

## CHAPTER 4

## TACTICS AND TECHNIQUES OF FIREFIGHTING

## Section I. FIRE CONTROL

## 4-1. Introduction

Fire control is **defined** as “retarding or reducing the rate of burning.” Extinguishment, on the other hand, is the complete elimination of the fire. Retarding or reducing the rate of burning would seem to be just a step in the process of extinguishment. But it can be an immediate objective in itself, for a successfully controlled fire makes it possible to **rescue** personnel before completely extinguishing the fire. When a building is completely engulfed in flames, the heat makes rescue impossible until it has been reduced by control. In structural firefighting, control is very important especially when rescue of personnel may be necessary or when there is a danger of the fire spreading. Because water is the principal extinguishing agent, the supply limitation is not usually a problem. Instead, water pressure and the volume in gallons per minute are generally the **most** important factors in this phase of fire protection. Another method of control frequently used in structural firefighting is called *covering exposures*. This means that when one **structure** is burning, other structures, especially those downwind, are protected to keep radiation and convection heat from causing these buildings to start burning. To prevent this kind of spreading, streams of water are applied to these exposed buildings. In this sense, then, control means the prevention of spreading rather than the reduction of fire in a particular area.

## 4-2. Fire Control Methods

Three methods are used in the control of fire :

**a.** Cooling or reducing the temperature below the ignition point.

**b.** Smothering or reducing the oxygen content within the fire area below the burnable limits. The atmosphere must contain at least 15 percent oxygen in order for a fire to burn.

**c.** Removing fuel from the vicinity of the fire, by valve or switch action, by the application of heavy streams of water, by firebreaks in the case of natural-cover fires, or by manual removal.

## 4-3. Extinguishment of the Different Classes of Fire

**a.** Class A fires require primarily water or an agent containing water so that the deep-seated embers in wood, cloth, and other class A materials may be reached by the cooling agent.

**b.** Class B fires may be extinguished with carbon dioxide ( $\text{CO}_2$ ), **monobromotrifluoromethane** ( $\text{CF}_3\text{Br}$ ), foam (mechanical and chemical), dry chemical (bicarbonate of soda), **potassium** bicarbonate (Purple **K**), and ammonium phosphate), methyl bromide, mineral soil, **water-fog**, aqueous film forming foam (AFFF) (trade name “light water”) or any other system of covering that excludes oxygen. AFFF extinguishes the fire and prevents flashback. Dry chemical **extinguishes** the fire immediately by conditioning the atmosphere, but does not cool the combustibles.

**c.** Class C fires are extinguished by (in order of preference) monobromotrifluoromethane, carbon dioxide, and dry chemical. When selecting an extinguishing agent for class C fires, consideration must be given to the electrical conductivity of the extinguishing agents. None of the substances listed above is a conductor of electricity. It is advisable to use **monobromotrifluoromethane** ( $\text{CF}_3\text{Br}$ ) or carbon dioxide ( $\text{CO}_2$ ) on class C fires whenever possible.  $\text{CF}_3\text{Br}$  and  $\text{CO}_2$  leave no residue and will not damage electrical equipment.

## NOTE

One more type of fire to be aware of is the compressed gas fire. ‘Technically this type of fire is rated as class B, and

agents listed for class B fires are used to extinguish it. The safest and best way of controlling this fire is to remove the fuel supply. This prevents the accumulation of explosive vapors that would occur if the fire were extinguished and the fuel

were allowed to continue to flow. Fires involving pressurized flammable gases, especially those heavier than air, such as liquefied (petroleum gases, should not be **completely** extinguished unless the flow of gas can be immediately stopped.

## Section II. FIRE DEPARTMENT HYDRAULICS

### 4-4. Introduction

Hydraulics is that branch of science which deals with the mechanical properties of water or other liquids and with the application of these properties in engineering. **Firefighters**, especially pump operators, **must** understand and be able to apply those principles of hydraulics which are essential to firefighting. Inadequate training or lack of experience in fire hydraulics can be extremely costly in lives and materiel.

### 4-5. Properties of Water

Water, the most common liquid, is also the most effective, in its various forms, for firefighting. To use it most effectively, however, one should know about its physical properties.

a. For all practical purposes, water is not compressible. It requires 30,000 pounds (13,608 kilograms) of pressure per square inch (6.45 square centimeters) to reduce its volume 1 percent. If water has a mineral content (such as salt) or is subjected to different temperatures, its characteristics will differ.

b. Water consists of two parts of hydrogen and one part of oxygen—a fact represented by the common chemical formula  $H_2O$ . One cubic foot (0.6283 cubic meter) of water weighs 62.6 pounds (28.35 kilograms). There are 231 cubic inches (3786.09 cubic centimeters) in 1 gallon (3.785 liters) of water and 1,728 cubic inches (28,312 cubic centimeters) in 1 cubic foot (0.0283 cubic meter) of water. One cubic foot (0.0283 cubic meter) of water contains 7.481 gallons (28.3156 liters). One gallon (3.785 liters) of water weighs 8.35 pounds (3.7876 kilograms). These figures are important and should be remembered.

### 4-6. Volume

It is often necessary to determine the volume of cylindrical and rectangular containers in order to know the weights and capacities of installed or reserve tanks and consequently how long they will

be of use. To compute volume, first find the area of a surface. For a square or rectangle, this is done by multiplying the length by the width ( $A = lw$ ). For a circle, the area is found by multiplying the diameter squared by 0.7854 (i.e.,  $A = D^2 \times 0.7854$ ) or by multiplying the radius squared by 3.1416 (i.e.,  $A = R^2 \times 3.1416$ , commonly written  $A = \pi R^2$ , where the Greek letter  $\pi$  (pi) means 3.1416). In hydraulics, the preferred formula is the first one:  $A = D^2 \times 0.7854$ . When going on from problems dealing with the areas of rectangles and circles to those involving the volumes of cylindrical and rectangular tanks, consider a third dimension, that of height, represented by the symbol  $h$ . The formula for the volume of a rectangular tank is  $V = lwh$ , meaning that the volume is found by multiplying the length by the width by the height. **For example:** How many cubic feet are there in a tank 5 feet (1.525 meters) by 4 feet (1.22 meters) by 10 feet (3.06 meters)? Substituting in the formula—

$$\begin{aligned} V &= lwh \\ &= 5 \times 4 \times 10 \\ &= 200 \text{ cubic feet} \end{aligned}$$

### NOTE

When computing volume, all dimensions must be in the same unit of measurement. For example, if the diameter of a cylindrical container is given in inches and the height is given in feet, the height must be converted to inches.

The tank contains 200 cubic feet (5.67 cubic meters), and it then becomes a simple problem to find its contents in gallons (or liters). There are 7.481 gallons in 1 cubic foot (1000 liters in 1 cubic meter), so 7.481 multiplied by 200 equals 1,496.2 gallons (1000 multiplied by 5.67 equals 5670 liters), the number of gallons in a 200-cubic-foot tank. For problems involving volumes of cylindrical tanks, use the formula  $V = D^2 \times 0.7854 \times h$ . **For example:** How many cubic feet are contained in a tank 12 feet (3.66 meters) high and 5 feet (1.525 meters) in diameter?

$$\begin{aligned}
 V &= D^2 \times 0.7854 \times h \\
 &= 5 \times 5 \times 0.7854 \times 12 \\
 &= 235.62 \text{ cubic feet}
 \end{aligned}$$

To find the number of gallons, multiply 235.62 by 7.481 to get approximately 1,763 gallons (6673 liters).

#### 4-7. Weight

a. Firefighters must know how to find the weight of a given quantity of water. For example, vehicles with a capacity of 1,000 gallons (3785 liters) actually have 8350 pounds (3785 kilograms) of extinguishing agent aboard (8.35 multiplied by 1,000), or more than 4 tons (3.628 metric tons) of water. Such knowledge would be necessary in making a decision about detouring or crossing a bridge of limited capacity.

b. It is also necessary to be able to determine the weight of a charged hose line, especially when only a limited number of personnel are available to move such a line. The futility of filling a 2½-inch (6.35-centimeter) hose with water before trying to move it to the point of operation is revealed after figuring the weight of water in a 50-foot (600 inches; 1524 centimeters) section. This is done by means of the formula—

$$\begin{aligned}
 V &= \frac{D^2 \times 0.7854 \times h}{231} \times 8.35 \\
 (\text{Metric System: } V &= \frac{D^2 \times 0.7854 \times h}{1000} \times 1)
 \end{aligned}$$

in which  $h$  is the length of the hose in inches,  $D$  is the diameter of the hose in inches, 231 is the number of cubic inches in a gallon (1000 is the number of cubic centimeters in 1 liter), and 8.35 is the weight in pounds of a gallon (1 kilogram is the weight of 1 liter).

$$\text{The } V = \frac{6.25 \times .7854 \times 600}{231} \times 8.35 \text{ equals}$$

approximately 106 pounds (42.8 kilograms) plus the weight of the hose, which is 65 pounds (29.5 kilograms) per section, a total of approximately 171 pounds (78 kilograms).

c. To pull four 50-foot (15-meter) sections of 2½-inch (6.35-centimeter) hose, totaling something over one-quarter of a ton of hose and water combined, up a ladder, becomes a formidable task. These calculations also show that 1,000 feet (305 meters) of 2½-inch (6.35-centimeter) hose, which is the length often carried on structural pumpers, weighs almost 2 tons (1.8 metric tons) when filled.

#### 4-8. Pressure

Water pressure is proportional to the depth of the water, which, in hydraulics, is stated in pounds (or kilograms) per square inch (6.45 square centimeters). A column of water 1 foot (0.305 meter) high exerts a pressure of 0.434 pound (0.197 kilogram) per square inch (6.45 square centimeters). Two columns of water, each 1 foot (.305 meter) high, one on top of the other, would exert 0.868 pound (0.3937 kilogram) per square inch (6.45 square centimeters) of pressure at the base. In other words, if a column of water 1 square inch in base area and 1 foot high weighs 0.434 pound, the effective pressure in pounds per square inch at any point in a column of water is equal to 0.434 multiplied by the height of the column above that point in terms of feet; this is expressed as—

$$P = 0.434H$$

in which  $H$  is the head in feet. Static pressure is the pressure exerted by water at rest. The static pressure may be determined readily, if the head is known by the formula  $SP = 0.434H$ . Back pressure or gravity pressure indicates the pressure in pounds per square inch (psi) exerted by a head of water against a pump lifting it to an elevated point. The solution is found by the same method—

$$BP = 0.434H$$

#### 4-9. Rate of Discharge

The rate of discharge is the quantity of water coming from an opening during a given period of time. It is calculated in gallons per minute (gpm).

a. When the rate of discharge is computed, two items must be considered: the diameter of the opening (nozzle) and the pressure of the flow. The rate of discharge is found by multiplying the diameter squared by the square root of the pressure times the constant 29.7; this is expressed as—

$$\text{gpm discharge} = 29.7 \times D^2 \times \sqrt{P}$$

For example, using this formula and table 4-1, if the diameter is 2 inches (5.08 centimeter) and the pressure is 36 psi, then:

$$\begin{aligned}
 \text{Discharge} &= 29.7 \times D^2 \times \sqrt{P} \\
 &= 29.7 \times 2^2 \times \sqrt{36} \\
 &= 29.7 \times 4 \times 6 \\
 &= 712.8 \text{ gpm (2697.7 liters per minute)}
 \end{aligned}$$

b. An open hose butt (no nozzle) or an average hydrant outlet is only about 90 percent as efficient as a nozzle tip in terms of water volume dis-

Table 4-1. Square Roots of Numbers 1 to 100

n	√n	n	√n	n	√n	n	√n	n	√n
1	1.	21	4.582	41	6.403	61	7.810	81	9.
2	1.414	22	4.690	42	6.480	62	7.874	82	9.055
3	1.732	23	4.795	43	6.567	63	7.937	83	9.110
4	2.	24	4.899	44	6.633	64	8.	84	9.165
5	2.236	25	5.	45	6.708	65	8.062	86	2.219
6	2.449	26	6.099	46	6.782	66	8.124	86	9.273
7	2.646	27	6.196	47	6.855	67	8.185	87	9.327
8	2.828	28	5.291	48	6.928	68	8.246	88	9.380
9	3.	29	5.385	49	7.	69	8.306	89	9.434
10	3.162	30	5.477	50	7.071	70	8.366	90	9.486
11	3.316	31	5.667	51	7.141	71	8.426	91	9.639
12	3.464	32	5.656	52	7.211	72	8.485	92	9.691
13	3.605	33	5.744	53	7.280	73	8.544	93	9.643
14	3.741	34	5.831	64	7.348	74	8.602	94	9.696
15	3.873	35	5.916	55	7.416	75	8.660	95	9.746
16	4.	36	6.	66	7.483	76	8.717	96	9.798
17	4.123	37	6.082	57	7.549	77	8.775	97	9.848
18	4.242	38	6.164	58	7.615	78	8.831	98	9.899
19	4.368	39	6.245	59	7.681	79	8.888	99	9.949
20	4.472	40	6.324	60	7.746	80	8.944	100	10.

charge. So, for calculating open-butt or hydrant discharges in gallons per minute, the formula just applied to nozzle discharge must be multiplied by 0.9. This gives :

$$\text{Discharge} = \sqrt{29.7} \times 0.9 \sqrt{P} \times 0.9$$

Applying this to a hydrant in the above example gives 713 gpm  $\times 0.9$ , or 64.52 gpm (1428.16 liters per minute). For all practical purposes, 712.8 and 641.52 would be rounded off to 713 (2698 liters) and 642 (1423 liters).

#### 4-10. Drafting

When fire hydrants are not available to supply water for firefighting purposes, it may be possible to obtain water by drafting from a static or semi-static source, such as a pond, lake, or river.

a. This is done by dropping one end of a hard suction hose into the body of water and connecting the other end to the intake side of the pump. The pump is started and a partial vacuum is created within the hard suction hose by a primer. When positive displacement pumps are used, no primer is needed. Atmospheric pressure exerted on the body of water forces the water up through the hard suction hose into the pump. The pump discharges the water, under pressure, through the discharge outlet.

b. Atmospheric pressure at sea level is 14.7 pounds (6.668 kilograms) per square inch (6.45 square centimeters). Water creates a gravity or

head pressure of 0.434 pound (0.1969 kilogram) per square inch (6.45 square centimeters). One pound per square inch has a head of  $1 \div 0.434$  or 2.304 feet (0.703 meter). Therefore, atmospheric pressure of 14.7 psi can raise water to a height of  $14.7 \times 2.304$  or 33.9 feet (10.34 meters) at sea level. However, it must be understood that this figure is theoretical and can be true only where a perfect vacuum can be created. Fire pumps, regardless of condition, cannot create a perfect vacuum. A fire pump in good condition should be able to raise water about 75 percent of the theoretical height, or about 25 feet (7.6 meters) at sea level. Atmospheric pressure decreases as altitude increases at the rate of about 0.5 psi per 1,000 feet (305 meters). At 5,000 feet (1525 meters) altitude, the atmospheric pressure is about 12.2 psi; therefore, water can be raised about 21 feet (6.04 meters) at this altitude.

c. When pumping from draft, be careful to assure that all gaskets are in good condition and seated properly in place. All connections must be tight. An adequate screen should be connected to the hard suction hose to prevent debris in the water from being pulled into the pump.

#### 4-11. Application of Water

Water is the most practical extinguishing agent for ordinary structural fires.

a. It absorbs heat rapidly and with greater capacity than most other agents used for fire ex-

tinguishment. A great amount of heat is required to raise cold water to the boiling point; much more heat is required to change the water to steam. However, only a small fraction of the theoretical maximum cooling effect is used if the water is applied in a solid stream.

**b.** To be effective, water must reach the base of a fire. A stream or spray directed into the smoke does little **more** than cool the atmosphere, unless it eventually falls upon the burning material. For large Class A fires, a **substantial** stream is necessary to penetrate the smoke, flame, and fuel. The most efficient fire stream is one which is forceful and large enough to do the job efficiently without excessive water damage. Solid fire streams project water over a considerable area and extinguish **otherwise** inaccessible fires. The production of this fire stream is the primary concern of the senior man, but is also the responsibility of other crewmen from the nozzle-men to the pump operator.

**c.** Some fires, even structural ones, can be extinguished more efficiently with a spray or fog stream, which requires greater pressure to be effective. Fog streams do not have the range of a straight 'stream, but the heat absorption is greater. Water damage is usually less when fog is used because much of the liquid is dissipated as steam. In a hot, smoky, interior fire, firefighters are usually more efficient and comfortable with a fog **stream** in front of them.

**d.** An efficient firefighter must be able to determine the extinguishment requirements of a fire and know the means available for meeting those requirements.

**e.** Extinguishment is **usually** simple if the fire is reached in the early stage, when it can be **extinguished** with a booster line or portable extinguisher.

**f.** If a fire is not discovered in the early **stage** of burning, extinguishment is usually difficult because the fire stream must not only produce the amount of water required for extinguishment but must also carry through space to the point of use. **Volume** can often be supplied with small streams, but even these streams must have shape and velocity to carry them efficiently to the base of the fire.

**g.** If a fire is not discovered or controlled until the entire building is burning, it can be extinguished only by the use of large quantities of water. Even then, the fire stream must be **con-**

trolled so as to supply the greatest amount of water from a safe distance and yet reach the fire at the point of burning. This stage of the fire required heavy master streams.

**h.** The fast-burning temporary frame structures, which have large areas unbroken by partitions, found on many military installations allow fire to spread rapidly. The use of **1½-inch (3.81 centimeters)** hose streams on most installations depends upon sound judgment resulting from the experience of the senior firefighter. The **1½-inch (3.81-centimeter)** hoses should not be used from pumpers unless ample **2½-inch (6.35-centimeter)** hose is available for support. If in doubt that a **1½-inch (3.81-centimeter)** line is capable of extinguishment, use a **2½-inch (6.35-centimeter)** line. Large streams from monitor nozzles and deluge sets may be used when equipment and adequate water supply are available and when the magnitude of the fire demands it.

#### 4-12. Friction loss

Friction is the resistance to motion between two surfaces in contact.

**a.** The term "friction loss" in fire department hydraulics means the loss of energy or pressure caused by friction. The friction conditions with **which** fire protection personnel are most concerned consist of water **rubbing** against the inside lining of the hose. This causes a turbulence of the water, which in turn sets up another friction, that of water rubbing against water.

**b.** The rubber linings of the hose appear perfectly smooth to the naked eye. But **microscopic** observation of hose linings shows a series of irregularities **which** increase in size as water pressure is exerted on the interior of the hose. These irregularities impede the speed of the water as it travels through the hose under pressure, causing friction loss, which, in turn, decreases the amount of flow pressure at the nozzle. The friction loss is always less than the amount of pressure available at the source, whether a **pumper** or a hydrant,

**c.** When dealing with friction loss in hydraulics, the law of pressure may be expressed as follows -the water pressure at the source **minus** the pressure lost on the way equals the pressure at the nozzle. The pressure acquired in the beginning is the **engine pressure**. The pressure lost on the way is the **friction loss**. The pressure which is left is the **nozzle pressure**. The conclusion is that engine pressure minus friction loss equals nozzle

pressure ( $NP = EP - FL$ ), or, to put it another way, nozzle pressure plus friction loss equals engine pressure ( $EP = NP + FL$ ). These formulas are strictly rule of thumb; they are not the technical formulas.

#### 4-13. Ideal Requirements

Now the nozzle pressure necessary to make a good fire-extinguishing stream can be determined.

a. A good stream for structural firefighting is one which has enough pressure to reach the fire in a solid mass. This means that it must have ample range and must not break into large fog particles or water drops before reaching its desired range. This ideal structural **fire-extinguishing** stream must be capable of discharging  $9/10$  of its volume in a **15-inch** (38.1-centimeter) circle at a distance of **50** to 100 feet (15 to 30.5 meters), depending upon the size and extent of the fire. Experiments have revealed that 40 to 60 pounds (18 to 27 kilograms) of nozzle pressure will do this. The mean or average nozzle pressure would then be **50** pounds per square inch (22.7 kilograms per 6.46 square centimeters); this is the accepted pressure.

b. Since the desired nozzle pressure is known, the amount of friction loss in any given hose layout must be computed and added to the 50 pounds of nozzle pressure; the sum of these two figures would be equal to the desired engine pressure. Friction loss varies in proportion to the square of the degree of increase in the **flow** of water. Thus, when the flow of water through a hose is doubled, the friction loss increases four times. For example, if 200 gallons (757 liters) of water per minute are flowing through a hose with a friction loss of 20 pounds (9 kilograms), an increase to 400 gallons (1514 liters) per minute **would** bring the friction loss to **80** pounds (36 kilograms).

#### 4-14. Factors Affecting Friction loss

Friction loss also varies directly with the length of the line.

a. This means that the total friction loss will vary with each hose layout. For example, if there are 10 pounds (4.5 kilograms) of friction loss in 100 feet (30.6 meters) of **2½-inch** (6.35 centimeter) hose using a 1-inch (**2.54-centimeter**) nozzle, then there would be 20 pounds (9 kilograms) of friction loss in 200 feet (61 meters) of the same hose using the same nozzle.

b. Friction loss increases very rapidly with decrease in the size of the hose. If the diameter of

the hose is doubled, the friction loss is only **1/32 as much** as that in the smaller line. If the diameter is halved, the loss is 32 times greater than the larger line. Thus, friction loss in **1½-inch** (3.8-centimeter) hose is **13½** times as great as in **2½-inch** (6.35-centimeter) hose, other conditions remaining the same.

#### 4-15. Siamesing

When two hoses **run** parallel into a single hose to **which** one nozzle is attached, they are said to be siamesed.

a. This frequently done to prevent excessive loss and thereby increase nozzle pressure. Friction loss in two **2½-inch** (6.35-centimeter) siamesed lines of the same length is only 28 percent as great as in a single line of **2½-inch** (6.35-centimeter); 26 percent may be used for rapid calculation.

b. For example, if there are 10 pounds (4.6 kilograms) of friction loss in 100 feet (30.5 meters) of **2½-inch** (6.35-centimeter) hose, there would be **13½** times 10 (4.5 kilograms) or 135 pounds (61 kilograms) loss in the same length of **1½-inch** (3.81-centimeter) hose, other conditions remaining the same. In two lengths of **2½-inch** (6.35-centimeter) hose siamesed in parallel lines, there would be  $1/4$  of 10 (4.5 kilograms), or **2½** pounds (1.134 kilograms) loss in discharging the same amount of water. This shows the value of a siamese connection, especially in the use of heavy streams where a large quantity of water is needed with greater pressure.

#### 4-16. Effect of Nozzle Size and Pressure

a. For all ordinary structural fires that have not advanced to the point of becoming an exterior conflagration, a 1-inch (**2.54-centimeter**) nozzle tip is used to keep water damage at a minimum while still having ample volume and pressure to extinguish the fire quickly and efficiently. A **1¼-inch** (3.2-centimeter) tip will discharge **1½** times as much water as a 1-inch (**2.54-centimeter**) tip, and a **2-inch** (5.08-centimeter) tip will discharge 4 times as much water as a 1-inch (**2.54-centimeter**) tip at the same nozzle pressure. The larger tips are used for large, advanced fires which require greater range and volume.

b. A 1-inch (**2.54-centimeter**) tip with **50** pounds (22.7 kilograms) of nozzle pressure will discharge slightly more than 200 gallons (767 liters) per minute with about 10 pounds (4.6 kilo-

grams) of friction loss for every 100 feet (30.5 kilometers) of **2½-inch (6.35-centimeter)** hose. So there will be a 10-pound (4.5 kilograms) pressure loss for each 100 feet (30.5 meters) of hose in use. Adding this friction loss to the desired nozzle pressure gives the engine pressure necessary to supply the nozzle pressure.

c. *For example*, in a 1,000-foot (**305-meter**) layout of **2½-inch (6.35-centimeter)** hose, using a 1-inch (**2.54-centimeter**) nozzle and desiring **50** pounds (22.7 kilograms) of nozzle pressure, the needed engine pressure is easily determined. Since there are ten **100-foot (30.5-meter)** sections in 1,000 feet (305 meters), with 10 pounds (4.5 kilograms) of pressure loss per 100 feet (30.5 meters) of hose, multiply the 10 sections by 10 pounds (4.5 kilograms) to get the pounds of friction (100) and add to it the 50 pounds (22.7 kilograms) of nozzle pressure required. This equals 150 pounds (68 kilograms) of engine pressure.

d. If the nozzle size is increased to **1½ inches (2.858 centimeters)**, maintaining 50 pounds (22.7 kilograms) of nozzle pressure, the flow of water increases to 265 gallons (1003 liters) per minute, with 18 pounds (8.165 kilograms) of friction loss for every 100 feet (30.5 meters) of **2½-inch (6.35-centimeter)** hose. If the nozzle diameter is increased to **1¼ inches (3.175 centimeters)**, the flow increases to 325 gallons (1230 liters) per minute, and the friction loss increases to 25 pounds (11.34 kilograms) for every 100 feet (30.5 meters) of **2½-inch (6.35-centimeter)** hose.

e. Friction loss for the five common nozzle sizes at 50 pounds (22.7 kilograms) of pressure is calculated in table 4-2. Every pump operator should memorize this table so that he can tell at once how much engine pressure is required for any type of layout that uses **2½-inch (6.35-centimeter)** hose.

f. When hose is laid or advanced to a level above the discharge outlet of the pump, the water in the hose exerts a pressure against the pump,

known as back pressure. This back pressure is determined by multiplying the height above the pump discharge outlet, in feet (0.305 meter), by 0.434, which is the pressure in pounds per square inch (6.45 square centimeters) created by 1 foot (0.305 meter) of water. In the army, each story of a building is considered as 12 feet (3.66 meters), so the back pressure for each story would be  $12 \times .434 = 5.208$  pounds (2.36 kilograms per 6.45 square centimeters), or approximately 5 psi (0.366 kilogram per square centimeter). *For example*, if the hose is advanced to the third story, which is two stories above the first,  $2 \times 5$  or **10** psi must be added to the pump pressure to compensate for the back pressure. The nozzle size that should be used is determined by the total length of a hose layout. In a short layout (up to 600 feet (183 meters)) a 1x-inch (**3.175-centimeter**) tip may be used. In a medium layout, 600 to 900 feet (183 to 274.5 meters), a **1½-inch (2.86-centimeter)** tip is used. A long layout, 900 feet or over (274.5 meters), ordinarily requires the use of the 1-inch (**2.54-centimeter**) tip. The tip size, however, may be changed at the discretion of the senior firefighter.

g. To illustrate all the preceding points, set up a situation involving 700 feet (273.5 meters) of **2½-inch (6.35-centimeter)** hose. This is a medium layout, calling for the use of a **1½-inch (2.86-centimeter)** nozzle. From table 4-2 it is known that the friction loss factor of hose and nozzle is 18 pounds (8.2 kilograms) per 100 feet (30.5 meters). Seven multiplied by 18 equals 126 pounds (57 kilograms) of friction loss; to this add the 50 pounds (22.7 kilograms) of nozzle pressure required; the result is a required engine pressure of 176 pounds (80 kilograms). If the hose is taken up to the fourth floor, three floors above the first, multiply 3 by 5 (pounds) to get 15 pounds (6.8 kilograms) of back pressure. Then add this 15 to 176 to get 191 pounds (87 kilograms) as the total engine pressure required. For all practical purposes the answer 191 would be rounded off to 190, or the nearest figure divisible by 5.

h. One of the most important factors that determine success or failure in combating structural fires is the effectiveness of the fire stream. A weak stream generally will not reach the objective. Too much pressure will cause a stream to break up and lose its effectiveness. It has been determined that 50 psi (22.7 kilograms per 6.45 square centimeters) nozzle pressure will, in most cases, result in a good effective stream. If the chief or crew

Table 4-2. Friction Loss of Nozzles at 50 Pounds of Pressure

Nozzle size in inches	Approximate friction loss in pounds per 100 feet of 2½-inch hose
¾	4
7/8	8
1	10
1½	18
1¼	25

chief in charge decides that less or more pressure is needed, he will order or signal the pump operator to decrease or increase the pressure. The pump operator should, however, set the initial nozzle pressure at 50 psi.

i. The pump operator of a structural pumper must be thoroughly familiar with all the equipment on the truck. He must know how many lengths of hose there are in each layer in the hose bed. When hose has been laid from the truck, the operator should be able to determine how much hose was used in the lay by glancing at the hose remaining in the hose bed. (Only an approximate estimate is necessary.) The pump operator can, by glancing at the nozzle tips remaining on the truck, determine what size nozzle tip is to be used. Knowing the amount of hose laid and the size of the nozzle tip, the pump operator determines what pressure must be maintained at the pump to produce 50 psi at the nozzle by referring to the pump operator's guide plate (fig. 4-1).

4-17. Pump Operator's Guide Plate

Most structural pumpers employed by the army are equipped with a pump operator's guide plate installed on the left side of the pumper directly over or near the pump operator's controls.

a. This plate (fig. 4-1) lists the pump pressures required to maintain a desired nozzle pressure for different size nozzle tips and hose lengths and is used merely as a guide by pump operators.

b. To read the guide plate, a pump operator must understand what is meant by "changeover valve" and what occurs within the pump when the valve is placed in either of two positions.

c. He must understand that the only pumps equipped with a changeover valve are multiple-stage pumps. The Class 530B or 530C pumper,

SIZE OF NOZZLE	GPM	PRESSURE OF NOZZLE IN POUNDS	LENGTH OF 2 1/2 INCH HOSE LAYOUT											
			100	200	300	400	500	600	700	800	900	1000	REQUIRED PRESSURE AT PUMP	
1"	209	50	62	73	84	95	106	117	128	139	150	160		
1 1/8"	266	50	69	86	103	120	137	154	171	188	205	222		
1 1/4"	326	50	78	103	128	155	178	203	228	253	278	303		

Figure 4-1. Pump operator's guide plate.

used by the army, have a single stage pump, however a two-stage pump is planned for the future. The two stage pump has two sets of impellers which operate from a single shaft. When the valve is placed in the "parallel" or "volume" position, the water entering the pump on the intake side is divided and delivered to both sets of impellers simultaneously. Then, as the impellers force the water out of each impeller housing, the two masses of water joins together before emerging from the discharge outlet. When the valve is placed in the "series" or "pressure" position, the water entering the intake side is delivered to one impeller, which forces the water through an outlet (orifice) to the other impeller which in turn forces it out at increased pressure through the discharge outlet,

d. The heavy zigzag line running down across the guide plate shows pressures required. This line divides the chart in half and is not to be considered when operating a single-stage pump. However, when operating a two-stage pump with a changeover valve and when pumping at a pressure listed to the left of the heavy line, be sure that the changeover valve is in the volume or parallel position. If pumping at a pressure listed to the right to the heavy line, see that the changeover valve is in the pressure or series position. Note that the pressures given in the chart are actual pressures, and that the pressure gages on various pumpers will vary in calibration. They may be calibrated in 2, 5, 10, or 50 psi. The policy is to set the pump pressure to the nearest calibration of the gage on that specific truck.

Section III. HOSE, LADDER, AND PUMPER DRILLS

4-18. Introduction

Hose,, ladder, and pumper drills performed under simulated fire conditions train firefighting personnel for an actual emergency.

a. The drills must be varied so that all the fire-protection equipment on the firefighting vehicle is used. These drills must be constantly practiced until the proficiency of both individual and crew in all the duties to be performed reaches a high level. After a high degree of skill is achieved, refresher drills must be carried out to retain it.

b. In the firefighting drills, each crewman has a series of assignments which must be quickly carried out in a precise manner and at the proper time. These assignments involve laying out the hose, putting the pump into operation, and erecting ladders on buildings. Since hesitancy on the part of a crewman could cause serious delay, and, in turn, serious fire damage and loss of life, these hose, ladder, and pumper operations must be understood and practiced until each man can execute them without a moment's hesitation.

c. It is difficult to specify a fixed procedure for drills, because of such variables as the aptitude of the crewmen, the frequency and intensity of training periods, and the conditions peculiar to each fire emergency and to each individual installation. Some general standards can be set up, however, although assignments will vary with each emergency.

#### 4-19. Special Purpose Rolls and Folds

When hose is used in a very **large** or high building, it is normally operated from a building **standpipe** system. This is a system of piping with outlets on each floor. A pumping engine should pump into this system to assure enough pressure for effective streams. As mentioned under the section on unlined fabric hose, the fire department advances its own hose from building standpipes. Where standpipe systems exist, hose should be carried that can be taken through **doors**, on elevators, and up stairways quickly. This hose **should** be compactly rolled or folded in such a way that it can be placed in service very quickly. Certain methods of rolling and folding hose are well suited for this use. Hose carried in these rolls and folds is also useful for extending lines or replacing burst lengths of hose. Often a carrying pack is employed which also contains wrenches, adapters to non-fire service threads on standpipes, and other tools.

a. **The Donut Roll.** The donut roll forms a compact roll with both couplings accessible. The hose will pay out quickly and easily, even with both couplings coupled, and does not kink. To form a donut roll lay the hose out flat (fig. 4-2), and pull the male coupling back so the hose is doubled back on itself, with the male coupling about 3 to 4 feet (approximately a meter) from the female. Stand at the folded end, and face the folded end with one foot on each side of the hose. Leave enough space in the fold to place one hand through the roll for carrying. Roll the doubled hose (fig. 4-2), keeping the top and bottom portions **alined** with your feet as you back up. When the roll is completed the male coupling should be a foot (0.3 meter) or so behind the female coupling, protected by the hose behind the female coupling. This protects threads from damage, or the nozzle if one is carried **preconnected**. If the roll is not exactly **alined** it can be flattened by laying it on the floor and stepping on it. If a second man is available to help in forming the donut roll, he can keep the hose **alined** and take up slack in the top

portion by pulling on the hose behind the male coupling. The first man would then face the coupling end to make the roll.

b. **The Double Donut Roll.** The double donut roll can be made up with two lengths of hose, and can also be used for a **single** length where carrying space makes a smaller but wider roll desirable. To roll a double donut with two lengths of hose (fig. 4-3), couple them together and lay the lengths flat, next to each other. Fold the loop that results at the coupled **couplings** back onto the **hose**. **Leaving** enough room for a hand hold, roll the hose toward the uncoupled couplings.

c. **Self Locking Start for Donut or Double Donut Roll.** The self locking start for donut rolls (fig. 4-3) will hold the roll in place when it is handled, and provides a **handle** for carrying. To form this feature the end fold or loop is brought out about 18 inches ( $\frac{1}{2}$  meter) on each side of the flat hose before the roll is started, folding it in once toward the couplings and laying it flat on the hose. When the roll is completed the loop left exposed on one **side** is passed through the other loop (fig. 4-4). By pulling on the hose that passes through the roll the second or locking loop is tightened. The roll can be carried by the first loop. To put the roll in service the loops are first disengaged.

d. **The Flat Single Length Fold.** A single length of hose can be folded compactly by laying the length flat (fig. 4-5), then bringing the couplings together on top of the hose and engaging them a few turns to insure they remain coupled. Fold the hose in from each end to within about a foot (0.3 meter) of the couplings, then fold one side over the other. Couplings are protected from damage. The hose can be carried easily and put in service quickly.

e. **The Standpipe Pack.** If a canvas, plastic, or leather bag is available, the hose can be accordion folded into it with couplings accessible. When the hose is coupled to the standpipe or the line to be extended, the line pays out from the bag (fig. 4-6). This bag can also serve to carry a spanner wrench and adapters for use if **standpipes** have non-fire service threads. A nozzle is usually carried connected to the line and often a gated wye is connected to the standpipe end of the hose. Hose appliances made of lightweight materials and hose of lightweight construction should be used for this purpose if available.

#### 4-20. Hose loads

a. *Use of Standard Methods.* Hose carried on fire apparatus is loaded so that it can be put to use quickly and easily at the scene of a fire. It must pay out from the hose bed smoothly, without kinking. Standard methods of loading hose beds are used to assure **that—**

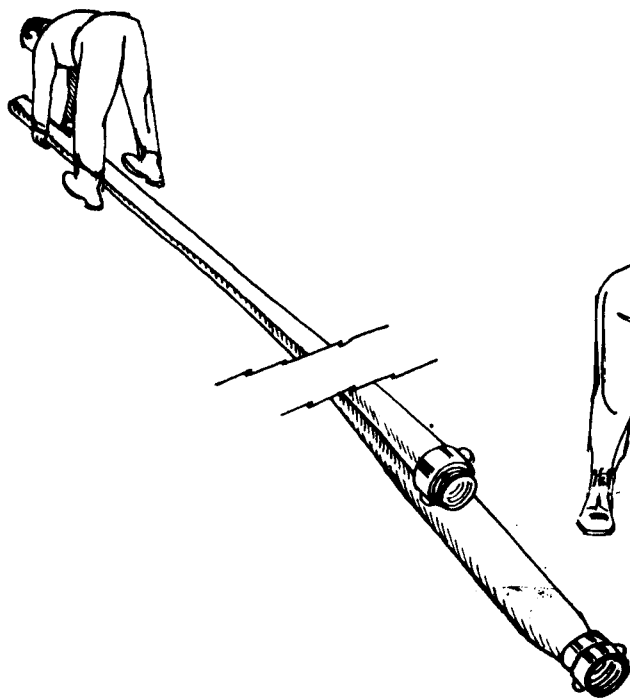
- (1) Hose will pay out easily, without binding.
- (2) Layers of hose will not settle into the

layers beneath, and become tangled.

(3) Hose will not be subjected to any more sharp bending than is necessary.

b. *Determining Which Standard Load to Use.* Several factors determine which of the standard loads should be used in a particular situation. The most important of these **are—**

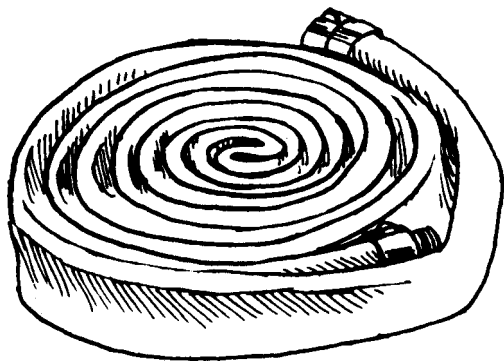
- (1) The size and shape of the hose bed.
- (2) The amount of hose to be loaded.



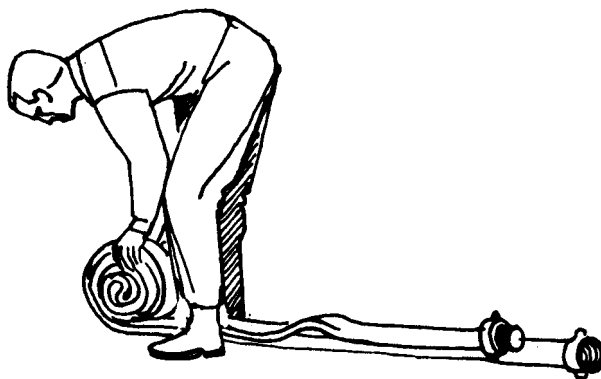
FORMING THE DONUT ROLL.



FORMING THE DONUT ROLL WITH TWO MEN.



COMPLETED DONUT ROLL.



DONUT ROLL PARTLY COMPLETED.

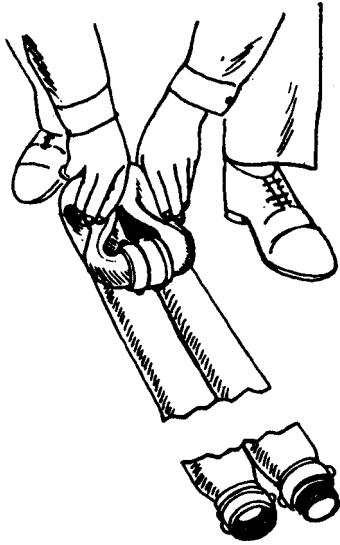
Figure 4-2. The donut roll.

(3) The purpose for which the hose will normally be used.

(4) The water system or location of drafting sources in the area.

#### 4-21. Apparatus Hose Beds

**a. Divided Bed.** Most hose carried on apparatus is loaded in a bed which is open to the rear of the



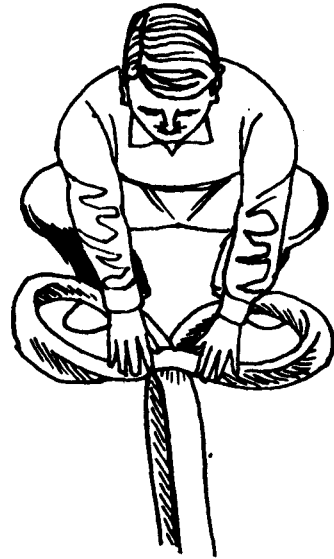
**BEGINNING** THE DOUBLE DONUT ROLL.



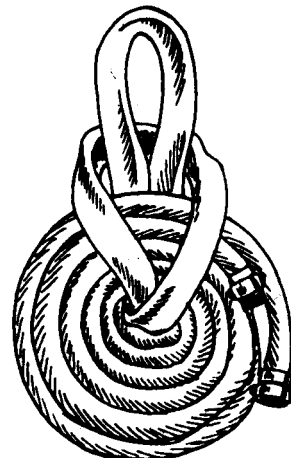
COMPLETED DOUBLE DONUT ROLL.

*Figure 4-3. The double donut roll.*

apparatus. To increase efficiency, beds are normally divided into two or **more** compartments (fig. 4-7), either by built-in partitions or by placing boards (baffle boards) in the bed as hose is loaded. Separate compartments are provided for **2½-inch** (6.35centimeter) and **1½-inch** (3.81-centimeter) hose (fig. 4-8). The term **divided load** is used to describe a load in which the larger size hose, **2½-inch** (6.35-centimeter), **3-inch** (7.62-centimeter) or larger, is divided so that two or more lines can be laid with a single movement of the apparatus. This is an advantage when the quantity of water to be moved is too great for a single line.

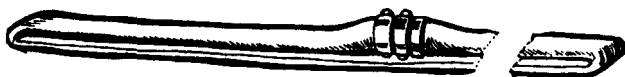


FORMING THE **SELF** LOCKING START FOR A DONUT ROLL.



COMPLETED DONUT ROLL WITH SELF LOCKING LOOPS.

*Figure 4-4. Self locking donut roll.*



BEGINNING THE SINGLE LENGTH FOLD.



SECOND STEP IN FORMING A SINGLE LENGTH FOLD.



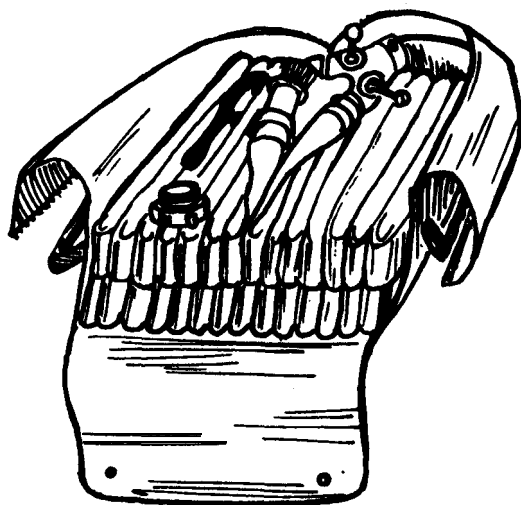
COMPLETED SINGLE LENGTH FOLD.

*Figure 4-5. The single length fold.*

**b. Cross Body or Transverse Hose Beds.** These beds are provided on some apparatus for attack lines, which can be taken off to either side. They are usually located behind the cab and can be reached quickly by men riding in or behind the cab. The lines are usually connected to a swivel fitting in the middle of the bed, which connects to piping from the pump. This allows the line to be taken from the side of the apparatus directly toward the fire, if there is room for both the engine and a ladder truck in front of the building on fire. Disadvantages of cross body hose beds include interference with the pump operator's use of the pump panel, and the short length of the bed, which is less than the width of the apparatus. Hose loaded in such beds has more sharp bends than where a longer bed is used.

#### 4-22. Functions of Hose lines

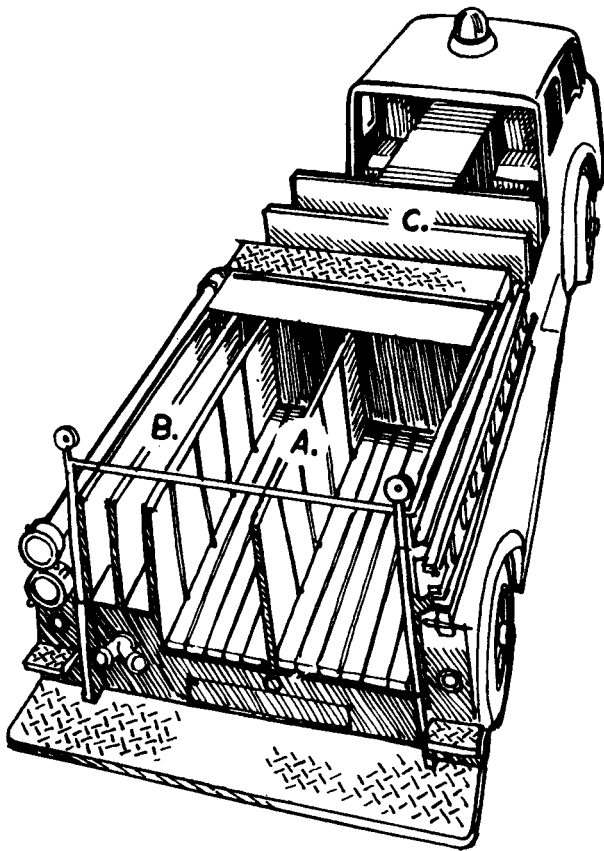
The **function—or purpose** for which normally used of a hose line determines how it is loaded and what type of hose is used. Lines that are

*Figure 4-6. The standpipe pack.*

normally used for supplying water to pumping engines, building sprinkler systems, or nozzles and master stream devices at major fires must be large enough to move large volumes of water efficiently. They should be capable of being laid by movement of the apparatus. **Preconnected 1½-inch (3.81-centimeter) or 2½-inch (6.35-centimeter) attack lines**, with nozzles attached and connected to piping from the pump, are designed to be put in operation quickly with the apparatus placed near the involved building. They are stretched by hand.

#### 4-23. Standard Loads

The methods used by fire departments for loading hose on main hose beds of a fire truck are the accordion load, the flat load, and the horseshoe load. These loads can be packed tight enough by hand to keep the layers from settling into each other as apparatus travels over the road. Tools such as bars and spanners should never be used to pack hose. This could result in damaging the hose, and in loads too tight to pay out easily. When loading hose it is important to locate couplings so they will pay out without turning in the bed. Turning couplings can wedge in the bed and may also fly up and injure men on the back step. To locate couplings properly, it is sometimes necessary to use a short fold when loading the bed. This is called a **dutchman**. The method for forming a **dutchman** is described under each of the standard loads. In beginning a load the coupling that is loaded first and will be the last off is placed at the rear corner of the bed so it can be seen when the load is completed. When a divided bed is used it is possible to connect the top cou-



A, DIVIDED MAIN BED  
B, BEDS FOR PRECONNECTED HOSE  
C, CROSSBODY OR TRANSVERSE BEDS

Figure 4-7. Hose beds.

pling in one bed with the bottom coupling in the next, so that a single long line can be laid without stopping. If the hose is not crossconnected, the visible coupling will show at a glance that the hose is not preconnected. In describing the various loads, the *front* of the hose bed is the end toward the apparatus cab, and the *back* or rear the end at the back step.

a. **The Accordion Load.** The accordion load consists of folding the hose back and forth lengthwise in the bed accordion fashion, with the hose on edge. The main advantage of this load is the ease with which shoulder loads can be formed for hand stretching lines. Its principal disadvantage is that it places many sharp bends in the hose.

(1) To form an accordion load, place the first coupling in the rear of the bed, next to the partition or baffle board that will separate the two parts of the main hose load (fig. 4-9). Take the hose to the front of the bed, standing on edge, fold 180°, and bring it to the rear alongside the first fold. Again fold 180 degrees and repeat the proc-

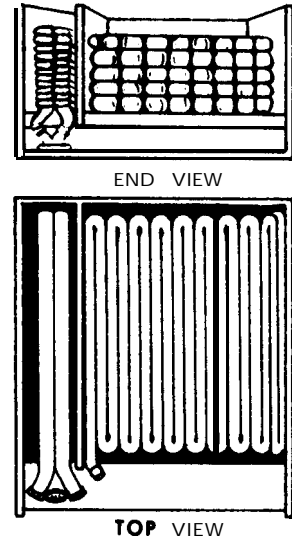


Figure 4-8. Divided bed.

ess. As each end fold is formed, stagger alternate folds with the first all the way to the end of the bed, and the next 2 or 3 inches (5 to 8 centimeters) short of the end. This keeps folds from coming directly opposite each other, which would make the ends fill up faster than the middle of the bed and would also make the folds sharper.

(2) To change the position of a coupling with a dutchman, take a short fold in the hose (fig. 4-10). This assures that the coupling will not turn in the truck bed when paying out.

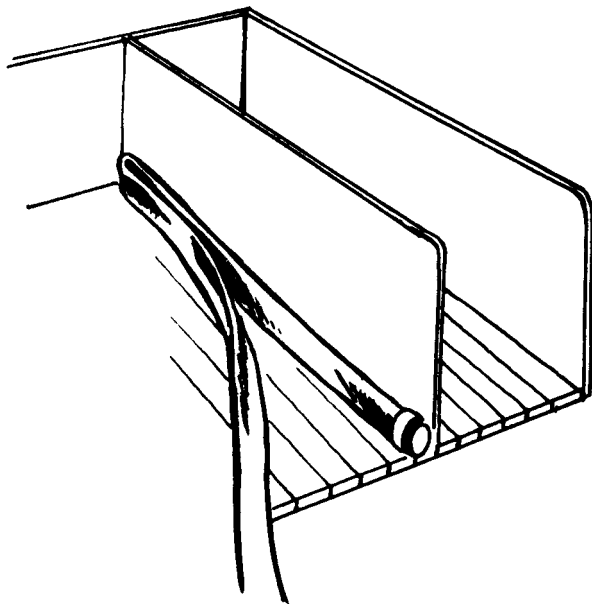
(3) When a layer is complete, the last 180° fold at the rear of the hose bed is made in the opposite direction of the other folds (fig. 4-11). This prevents kinking when the hose is laid. The hose is then tucked between the two previous folds and taken to the front of the bed, rising gradually to the top of the first layer at the front of the bed. It is then either brought straight back, beginning the next layer, or carried across the front of the bed to begin the second layer on the same side as the first.

b. **The Flat Load.** The flat load consists of folding the hose back and forth lengthwise in the bed, with the hose flattened (fig. 4-12). It pays out very easily and produces a straighter lay than the accordion load. However, it is more difficult to form shoulder loads for hand stretching from the flat load than from the accordion load. Both loads have many sharp bends in the hose.

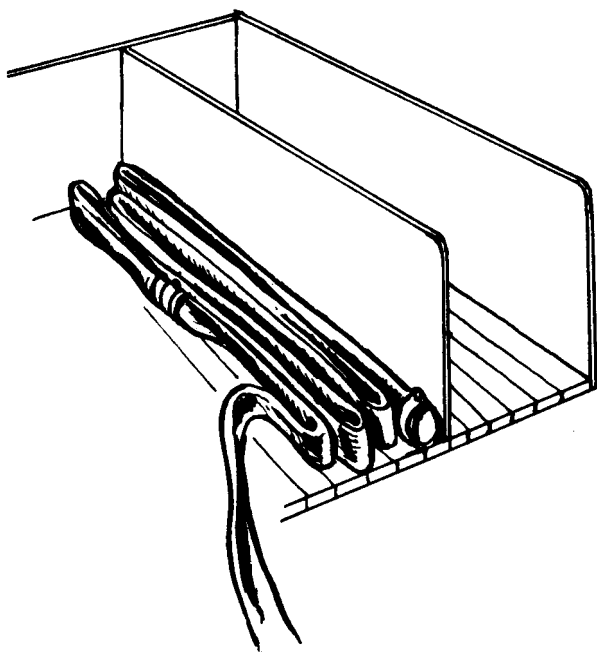
(1) To form a flat load, place the first coupling in the rear corner of the bed next to the partition or baffle board that separates the two parts of the main hose load (fig. 4-12). Lay the

hose to the front of the bed, fold it 180 degrees, and bring it to the rear at a slight diagonal to place the second fold next to the first coupling. Fold 180 degrees and repeat the process. Keep the end folds even.

(2) To change the position of a coupling, make a short fold (dutchman) as with the **accor-**



BEGINNING THE ACCORDION LOAD



FORMING THE ACCORDION LOAD NOTE STAGGERED FOLDS.

Figure 4-9. The accordion load.

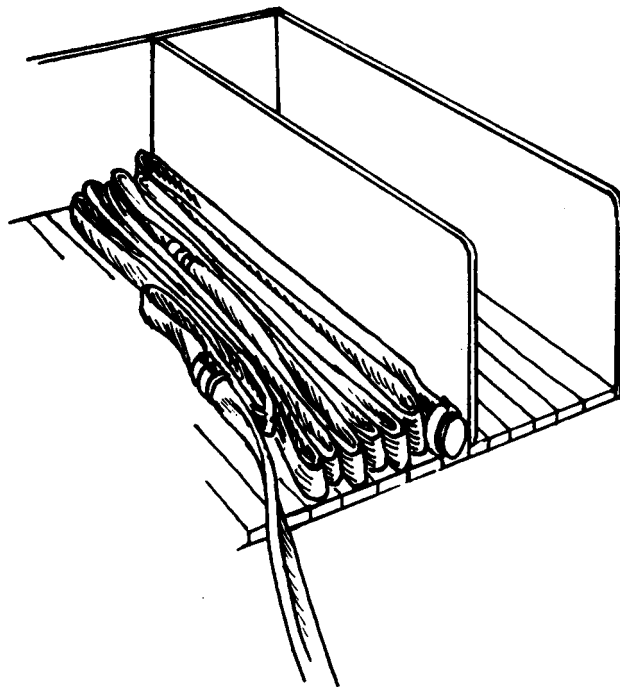


Figure 4-10. Forming a dutchman.

dion load, except that the fold will be doubled back **on** itself rather than placed next to itself (fig. 4-12).

(3) When the first layer is complete, begin the second by laying the hose diagonally in the opposite direction (fig. 4-12). The layers are formed in the same manner as the first layer, except that in alternate layers the **end** folds at each end are staggered by 2 or 3 inches (5 to 8 centimeters) so that the bends will be less sharp and the ends will not fill up faster than the middle of the bed.

c. **The Horseshoe Load.** The horseshoe load consists of hose loaded around the sides and front of the **bed** so that its shape roughly **resembles** that of a horseshoe. It has the advantage of less sharp bends in the hose, but does not lend itself readily to forming shoulder loads for hand stretching.

(1) To form the horseshoe load, place the first coupling next to the partition or baffle board that separates the two parts of the main hose load (fig. 4-13). Lay the hose to the front of the bed with the hose lying on edge, fold the hose 90 **de-**Agrees, **and** lay it across the front of the bed to the opposite side. Make a 90° fold and lay the hose to the rear of the bed. Then fold it 180 degrees **and** repeat the process. Stagger the 180 degree folds at the rear of the bed as shown in figure 4-13.

(2) Coupling positions can be changed by use of a short fold (dutchman) as **with** the accordion

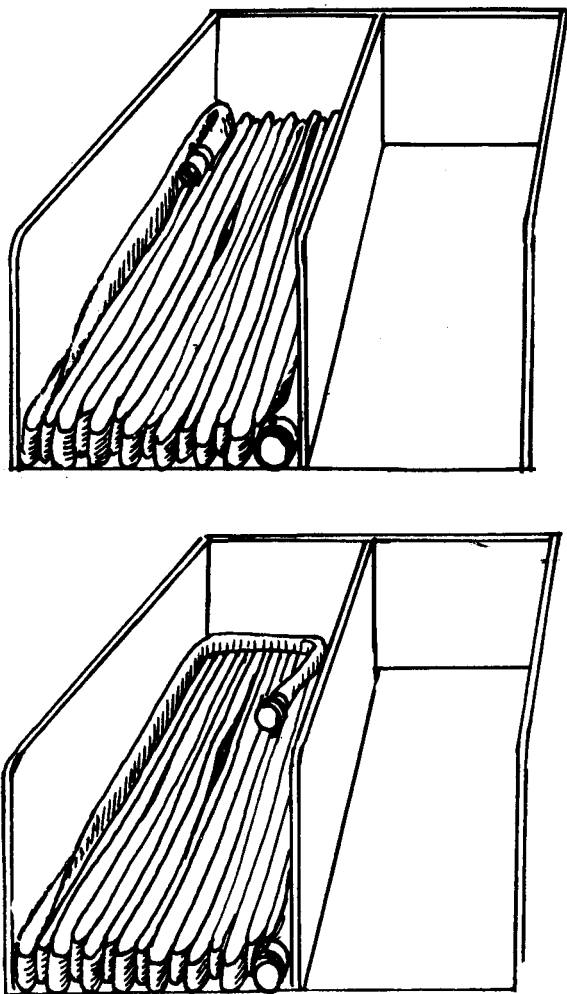


Figure 4-11. Two methods of starting second layer of accordion load.

load or by taking an extra fold across the front of the bed (fig. 4-14).

(3) A new layer is started by bringing the hose to the rear of the bed (fig. 4-15); across the end of half of the layer, and then gradually rising as it is being brought to the front of the bed. An alternate method (fig. 4-15) may be used in which the last fold of the layer toward the front of the bed is brought up, laid flat, and placed diagonally to a front corner. Then the hose is folded to bring it up on edge and laid in the same way as the layer laid previously.

#### 4-24. Hose load Finishes

Hose load finishes have two primary purposes—to provide hose line at the fire area with a minimum amount of effort and for convenience in hooking up to a hydrant. The finishes must provide a loosely loaded hose that will pull off the truck and

pay out easily. The method adopted is governed by the local conditions and the preferences of the fire chief.

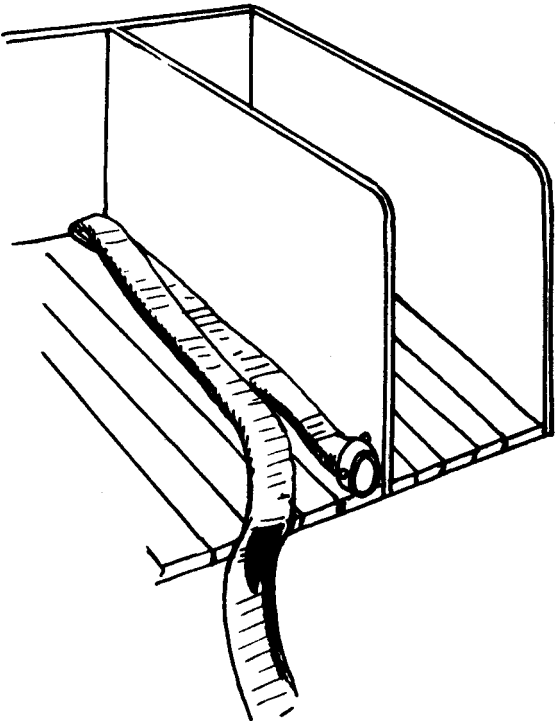
*a. The Donut Finish.* The donut roll, described in paragraph 4-19a, can be used to finish a hose load (fig. 4-16). It provides 50 feet (15 meters) of hose to facilitate hooking up to a hydrant or advancing attack lines. When a load is finished with a donut roll a second length of hose is usually placed (flaked) loosely back and forth across the top of the load so the donut can be carried off easily.

*b. Cross Fold or Riprap Finish.* This finish consists of loading the last length or two in a loose accordion fashion across the hose bed on top of the load (fig. 4-17). It will pay out freely, and a bundle can be grasped under the arm when stepping off to catch a hydrant.

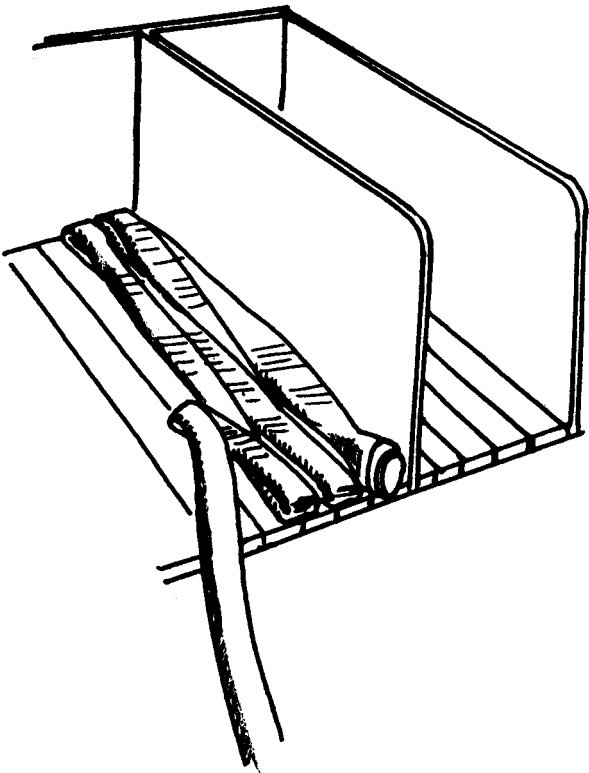
*c. Skid Load Finish.* The skid load is used to finish a load for working attack lines when the reverse lay is employed. About 15 feet (4.5 meters) of hose is loaded starting at the front of the bed with a cross fold (fig. 4-18). The hose is then turned flat and brought to the rear of the bed about 12 to 18 inches (30.6 to 46 centimeters) from the side of the bed. It is allowed to hang over the rear edge of the load about a foot (30.6 centimeters) 180°, and taken back on itself to the front of the bed. Here it is folded to run at a right angle to a point the same distance from the opposite end of the load, folded again, and brought to the rear and back to form a second skid (fig. 4-18). At the front of the bed the hose is brought up on edge and loaded in a cross fold on the two skids (fig. 4-18). The ends of the cross fold are kept 3 to 6 inches (7.6 to 15 centimeters) from the sides of the hose bed so the load will not dislodge when laying out. A nozzle can be attached and placed on top of the cross folds (fig. 4-18). A 2½-inch (6.35-centimeter) by 1½-inch (3.81-centimeter) reducing wye can be coupled to the 2½-inch (6.35-centimeter) hose and a line of 1½-inch (3.81 centimeter) hose, or two lines folded together, used to complete the skid load. Care must be taken that all couplings and appliances used in the skid load rest on the skids or on top of the cross fold position.

#### 4-25. Inspection and Maintenance

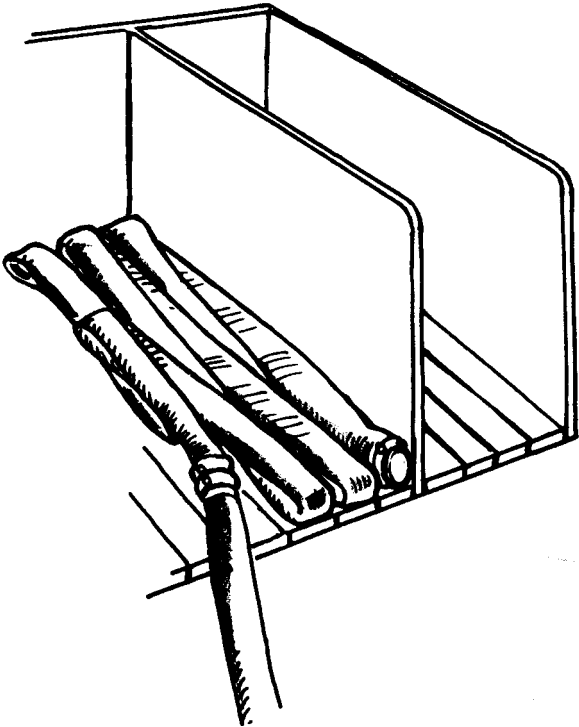
All hose and fittings should be inspected monthly, and after each use they should be washed and inspected again.



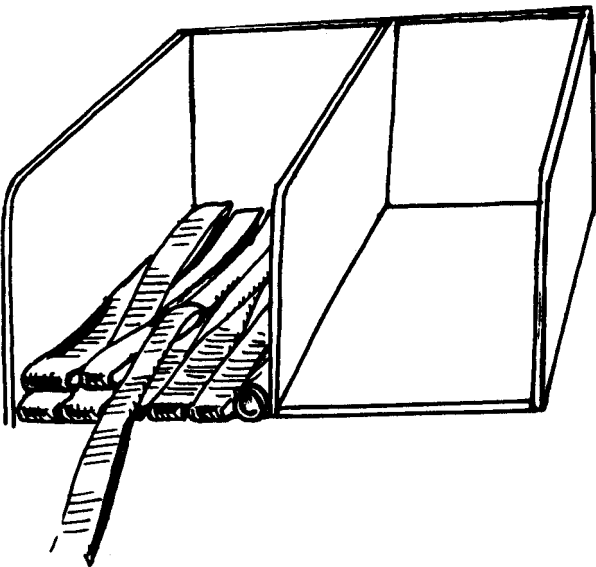
BEGINNING THE FLAT LOAD



FORMING THE FLAT LOAD



BY FOLDING THE HOSE BACK ON ITSELF



THE SECOND LAYER NOTE THAT FOLDS ARE STAGGERED FROM THOSE IN FIRST LAYER

Figure 4-12. The flat load.

a. When inspecting hose, go over the jacket thoroughly for breaks or worn spots. Look closely where the hose enters the coupling to see if there is any sign of the coupling coming loose. Look inside the coupling for damaged or slipping expansion rings. Inspect the swivel of the female couplings for damage.

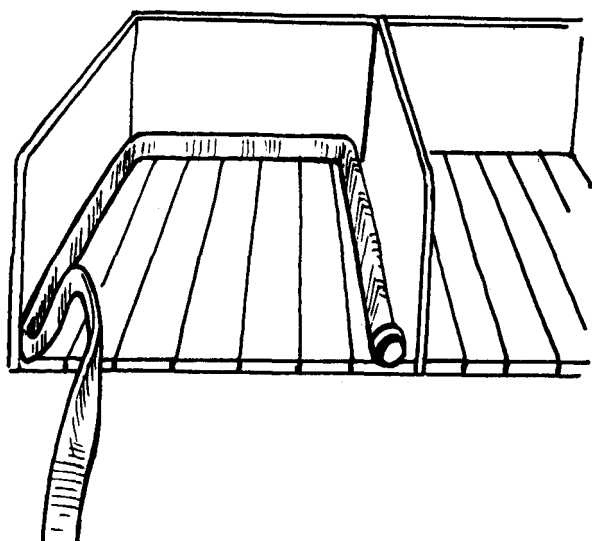
b. Any damage to hose should be reported immediately to the crew chief in charge and recorded on the hose record card. The threads of couplings should be cleaned thoroughly with a wire brush and a small amount of powdered

graphite or mild soap solution should be applied to them.

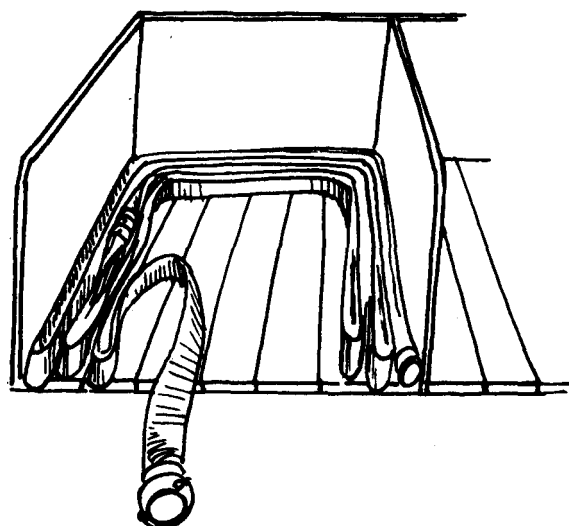
#### 4-26. Hose **layouts** and **Carries**

The preceding paragraphs covered the various methods of loading hose on a firetruck. Additional preparation is that of hose layouts and advancement to fires. Time is not so important when loading hose, but the process requires the utmost skill and cooperation because it is an important factor in hose layouts. There are only two hose layouts used in the Army: the *straight* lay and the reverse lay (which is the standard Army hose lay),

a. ***Straight Lay.*** The straight lay (fig. 4-19) is made as follows: On the approach to a fire the truck stops at a hydrant chosen by the crew chief. The hydrant should be as near the fire as possible without endangering the truck or driver, should the fire spread. The **plugman** steps off with enough line, and while he takes a turn around the hydrant with the hose, the truck proceeds to the fire. The



BEGINNING THE HORSESHOE LOAD.



FORMING THE HORSESHOE LOAD.

**NOTE** STAGGERED FOLDS.

Figure 4-13. The horseshoe load.

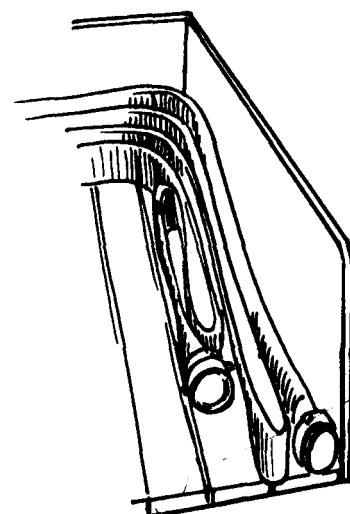
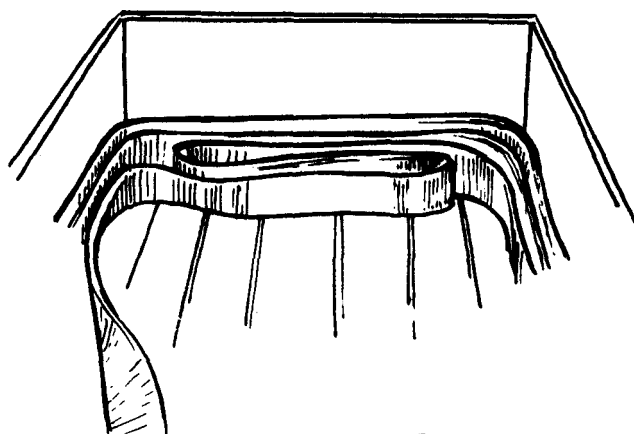
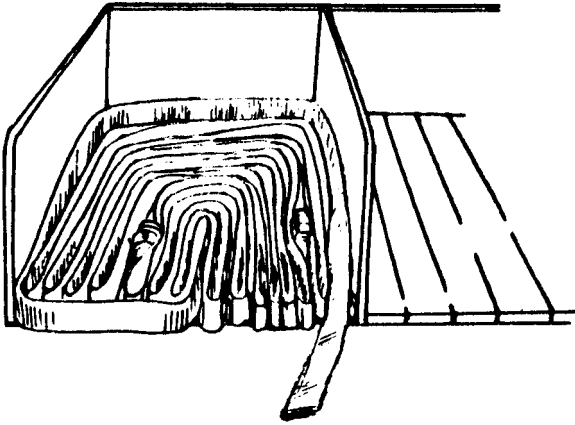
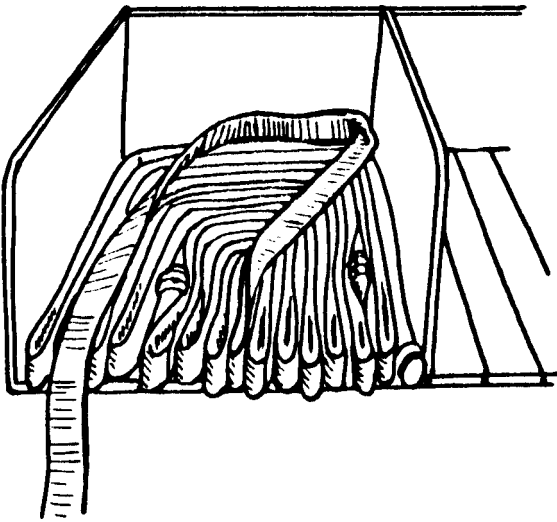


Figure 4-14. Two methods of forming a dutchman with the horseshoe load.



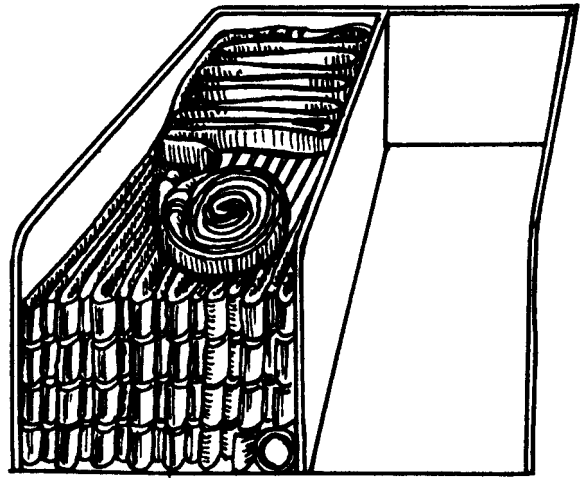
STARTING A SECOND LAYER OF THE HORSESHOE LOAD.



ALTERNATE METHOD OF STARTING A SECOND LAYER.

*Figure 4-15. Second layer of horseshoe load.*

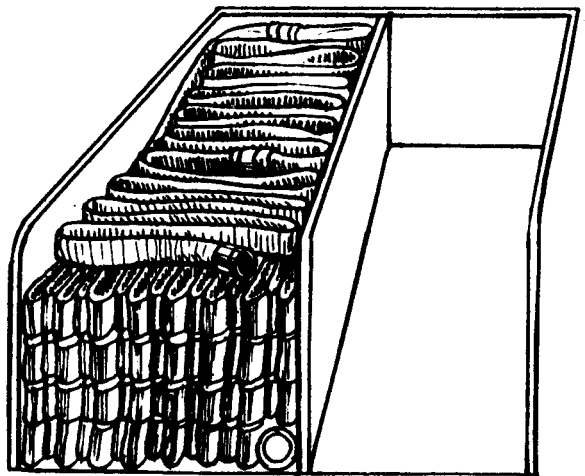
plugman removes the 2½-inch (6.35-centimeter) cap nearest the fire, connects the hose, removes the loop that is around the hydrant, opens the hydrant with his hydrant wrench, and proceeds to the fire, straightening out kinks or bends in the hose on the way. When the truck arrives at the fire, a hose clamp is applied to the hose, and enough working line (determined by the crew chief) is removed from the truck by a **hoseman**, who grasps one or more folds and walks backward till the loop or loops are clear of the truck. Then he goes back to the truck and repeats the procedure. He lays each loop nearer the fire. When enough hose has been removed, he disconnects the nearest coupling, puts the loose end back in the truck bed, and connects the nozzle to the hose. He then removes the hose clamp from the hose. He can then advance to the fire.

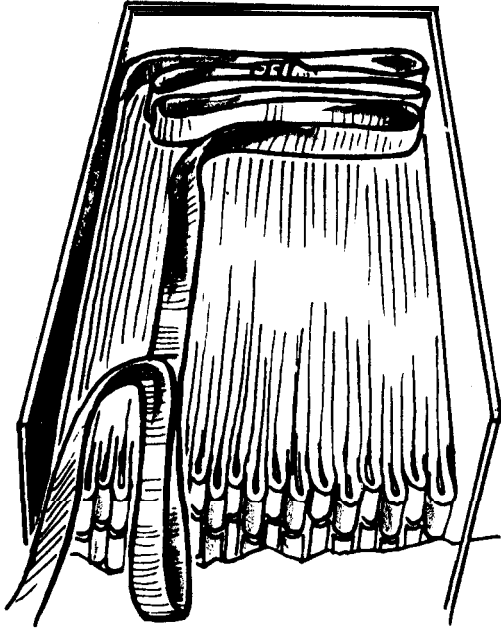
*Figure 4-16. Donut roll finish for hose load.*

## NOTE

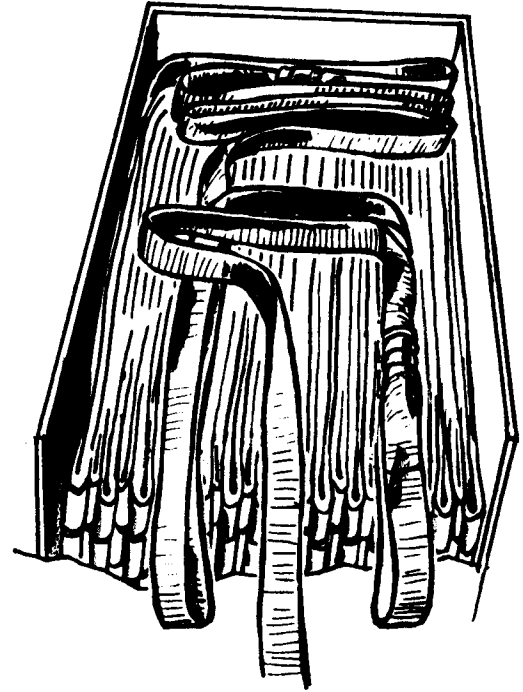
It is a good practice for the driver, if possible, to stop the truck about 75 to 100 feet (23 to 30.5 meters) beyond the nearest point to the fire. This will give the **hoseman** that much additional working line.

The straight lay, particularly if a long 2½-inch (6.35-centimeter) supply hose line is used, car supply only 1½-inch (3.81-centimeter) hose line; and the pumper can be used only to a fraction of its capacity. The straight lay should be used with caution and only for a 1½-inch (3.81-centimeter) hose stream fire without possibility of development into a 2½-inch (6.35-centimeter) hose stream fire. The straight lay may be used under certain circumstances if a second pumper is positioned at the hydrant.

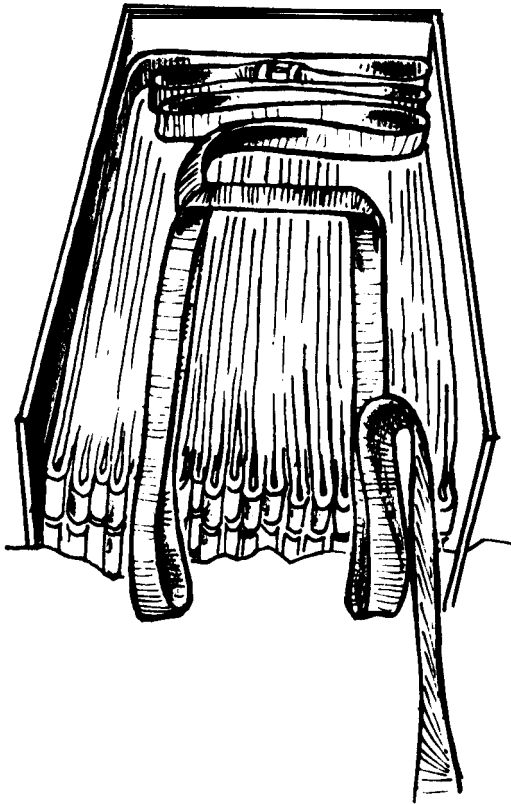
*Figure 4-17. Cross fold finish for hose load.*



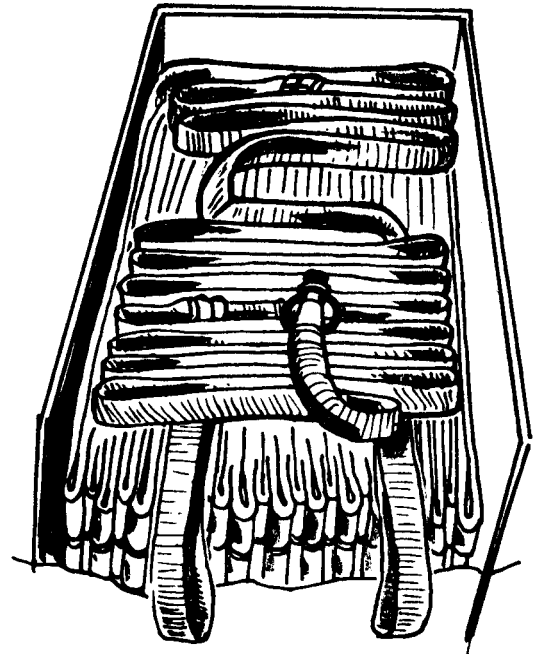
BEGINNING THE SKID LOAD FINISH.



FORMING THE CROSS FOLD PORTION OF THE SKID LOAD FINISH.



FORMING THE SECOND SKID.



COMPLETED SKID LOAD FINISH FOR HOSE LOAD.

Figure 4-18. Skid load finish.

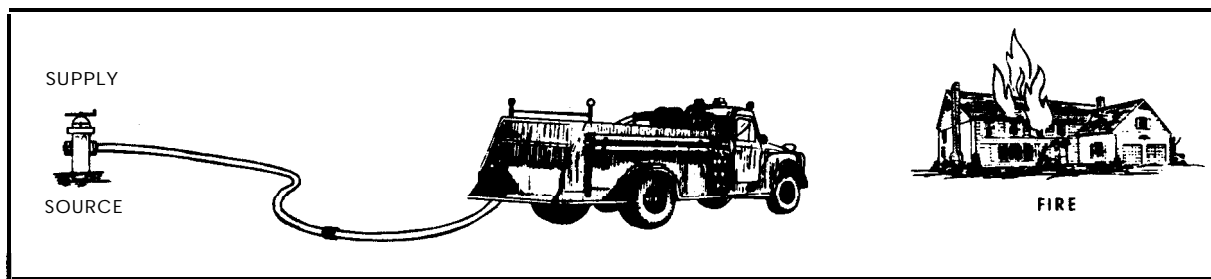


Figure 4-19. Straight lay.

**b. Reverse Lay.** When using the reverse lay, the hosemen lay hose from the fire to the hydrant (fig. 4-20).

(1) The pumper can be used to capacity and  $2\frac{1}{2}$ -inch (6.35centimeter) hand lines used only when the pumper is positioned at the hydrant and taking suction through a  $4\frac{1}{2}$ -inch (11.43-centimeter) hose.

(2) To make the reverse lay, the following procedures should be used. The truck should stop 75 to 100 feet (23 to 30.5 meters) short of the nearest point to the fire. (This will give additional working line.) The hosemen remove the working line by pulling a "skid" or other hose load. When the working line is removed, the nozzle men start advancing the line to the fire. While the nozzle men are occupied, the crew chief, driver, and plugman remove other equipment that may be needed, such as ladders (extension and roof), forcible-entry tools, portable lights, and pike pole. This equipment should be placed off the road and on the fire side of the truck. The crew chief kneels on the hose line to anchor it as it pays out, and then proceeds to the fire to aid and supervise the nozzle men.

#### NOTE

This procedure is flexible. The crew chief may have one of the hosemen anchor the hoseline while he proceeds to the fire.

The driver and plugman remount the truck, the plugman riding on the side to avoid injury from hose and couplings as the load is paying out. Making sure that a crew member is anchoring the hose, the driver drives the truck to the hydrant. He then puts the pump in gear, dismounts, disconnects the hose at a coupling (making sure there is enough hose to reach the pump), returns the loose end of the hose to the hose bed, carries the end of the hose that leads to the fire around to the pump on the side opposite the hydrant, and connects the hose to the discharge outlet of the pump. He may, if necessary, assist the driver in connecting the suction hose to the hydrant. The hydrant valve is then opened. The plugman proceeds to the fire, checking the hose line for leaking couplings and kinks, and reports to the crew chief. The driver remains at the pump controls at all times while the pump is being used.

**c. General Principles of Layout.** Any crew making a layout during drill or actual emergency must understand the principles of fire hydraulics in order to compute such things as friction loss. Hose layouts, such as siamese operations, may be carried out during drill periods, depending upon the potential firefighting demands of the individual base. In areas where the possibility of extensive fires exists, it may be well to concentrate on drills containing layouts where large water volumes and pressures may be required. It may be advisable under these conditions to establish a

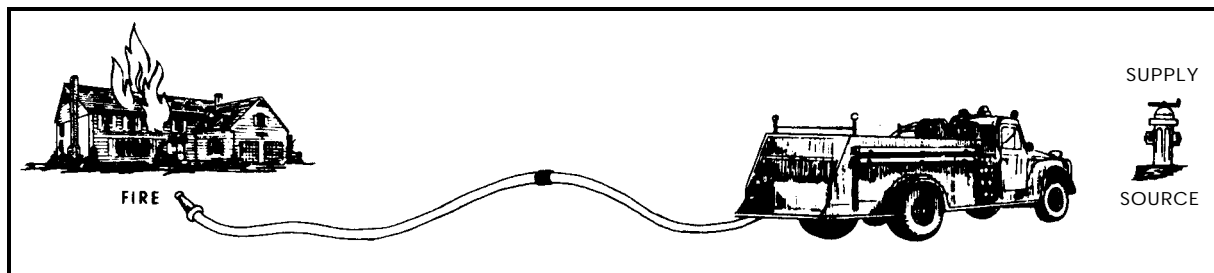


Figure 4-20. Reverse lay.

preassigned procedure for each piece of apparatus where the fire hazard exists. The pieces of apparatus which would normally be first in, or first to arrive at the scene of a potential fire, should be given priority.

**d. Advancing the Lines.** The most commonly used method of advancing the line is as follows :

(1) The nozzleman faces away from the fire, puts the hose over his left shoulder with the nozzle hanging downward at his back, and turns to the left facing the fire; the hose will extend across his chest and in under his right arm (fig. 4-21). He then advances to the fire.

(2) Personnel to the rear of the nozzleman carry the hose by means of the shoulder carry and the underarm carry (figs. 4-22 and 4-23). When using the shoulder carry, the carriers must place the hose on the same shoulder as the nozzleman uses. The underarm carry is particularly good for advancing lines at street level. Underarm loads may be picked up easily and quickly.

**e. Advancing Hose up a Ladder.** A 2½-inch (6.35-centimeter) hose should always be advanced up a ladder with a dry line if possible.

(1) A hose full of water is difficult to move or maneuver. If the line is already charged, time and effort are saved if the line is first broken and drained before any extensive advancement is attempted.



Figure 4-21. Carrying a hose forward.



Figure 4-22. Shoulder carry.

(2) In advancing an empty line up a ladder, the men climb about 10 to 12 feet (3 to 3.7 meters), with the hose on their shoulders and 20 to 25 feet (6 to 7.6 meters) between them (fig. 4-24). As the operation progresses, additional hose must be fed or passed to the men on the ladder to prevent the line from becoming fouled. When enough hose for adequate maneuvering has reached the desired height, the hose line should be anchored with a rope hose tool, chain, or strap to a fire well, a window sill or the ladder itself. The anchor should be made directly below the coupling to remove the strain of the hose and water weight from the lineman.

**f. Advancing Hose Up A Stairway.** Hose is difficult to drag even in an open, unobstructed area, and it is very difficult to maneuver around obstructions, such as those offered by a stairway. Time and energy may be saved if the hose is carried. The underarm carry is superior for stairway work under most conditions (fig. 4-25). If the hose has been properly removed from the apparatus, a man can quickly grasp an armful, since it lies in an orderly position. Again, advancing the hose is much faster and easier if the line is kept dry until the fire is approached; this can be done by keeping the hose clamp in place until the proper time for its release.



Figure 4-23. Underarm. carry.

g. *Advancing Hose With a Handline.* It frequently becomes necessary to take a hose line to an upper window or over a roof parapet with a handline. The line should be dropped from above by someone who has already carried the coiled **handline** to the desired level. Hose lines should be hoisted dry whenever possible, even if this requires **draining** a line. It is usually faster to **do** this than to attempt to hoist a **charged** line. In hoisting the line, it is **doubled** back so that the nozzle is about 4 feet (1.22 meters) from the end (fig. 4-26). A clove hitch is tied around the nozzle and hose, securing the nozzle a few inches behind the tip, with the standing end of the rope on the opposite side of the doubled hose from the nozzle (1). Next a half hitch is taken around the hose about a foot from the end (2). As the hose is hoisted, the **standing** end of the rope is kept between the building and the hose if possible, to prevent unnecessary damage to the hose. A man on the ground guiding the hose can assist in maintaining this position.

#### 4-27. Replacing a Section of Hose

A hose line does not normally burst when equipment is properly handled, maintained, and inspected. Nevertheless, it happens, and any fire organization will suffer serious consequences if

drills and precautions against burst lines are not undertaken. If a hose bursts, either the ruptured section of hose must be replaced, or a **short** line must be extended; either procedure requires shutting down the line by kinking it (fig. 4-27) or by using a hose clamp. The hose clamp is normally used if it is immediately available; if not, the line **may** be kinked behind the coupling to save the time required to go back to the hydrant. The replacement section is brought to the point where it is to be inserted, care being taken that the couplings are not dragged, dropped, or damaged in moving and that the male and female coupling are placed to make proper connection. Manpower permitting, the ruptured section should be removed while the replacement section is being carried from the apparatus. To save time, both connections should be made **simultaneously**.

#### 4-28. lengthening a Hose

Every precaution must be taken to **provide** enough hose for whatever maneuvering may be required to reach any portion of the structure involved in fire or any nearby structures which may be ignited by the original fire. Frequently, **1½-inch** (3.81 centimeter) lines are fed by a **2½-inch** (6.35-centimeter) line for confined spaces and **for** overhaul purposes. This requires that the

larger line be advanced when necessary and demands surplus or additional lines. When a line must be lengthened, two men remove two lengths (or 100 feet (30.6 meters) of hose) from the truck, and, using the shoulder carry, proceed to the end of the line (fig. 4-28). When the second man is about 25 feet (7.6 meters) beyond the end

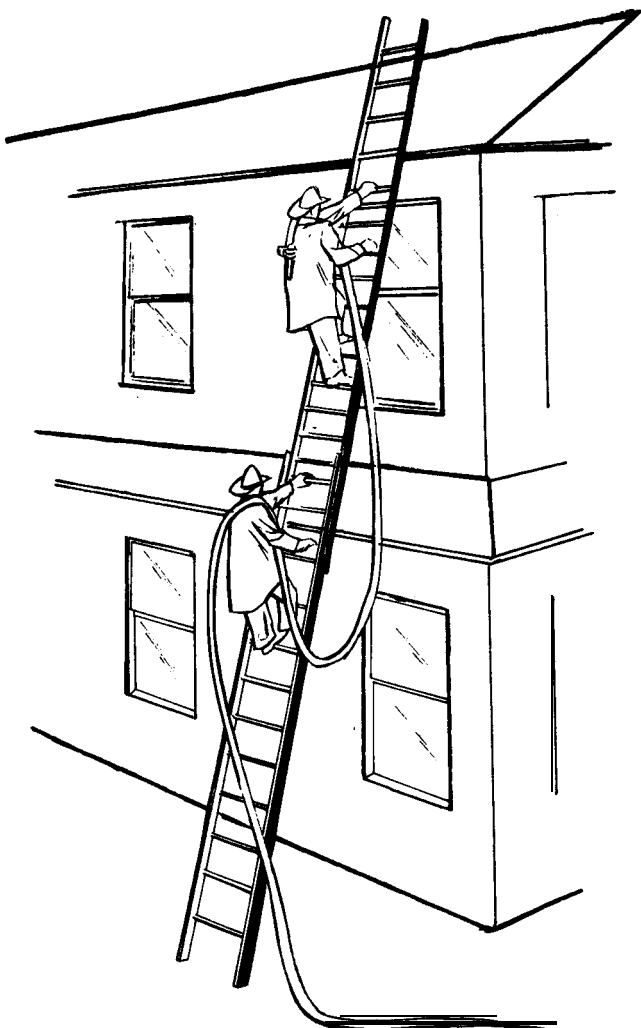
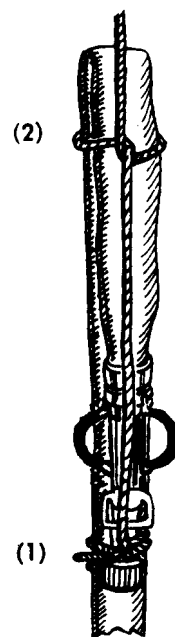


Figure 4-24. Advancing a hose up a ladder.



Figure 4-25. Advancing a hose up a stairway.



DRY LINE

Figure 4-26. Hoisting hose with a handline.

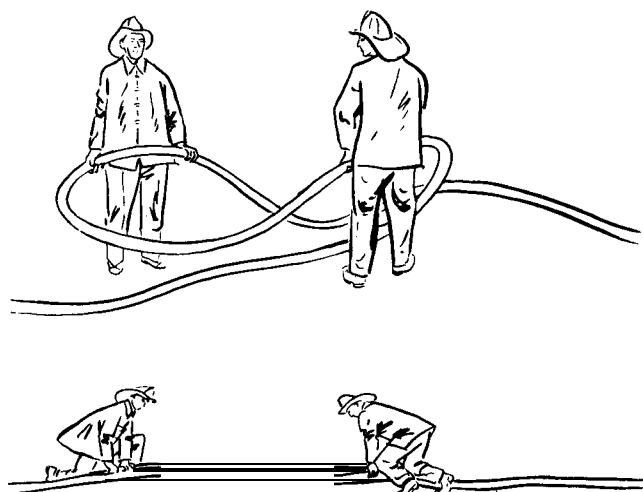


Figure 4-27. Kinking a hose line to stop flow.

of the line to be lengthened, he drops the hose, lays the coupling on the ground, and goes back to make the connection. The line is coupled while the first man continues on, paying off hose from his shoulder. After completion of the connection, water is readmitted into the hose when the signal is given.

#### 4-29. Controlling a Charged line

Working on a ladder sets up unstable conditions especially when a charged hose line is being handled. To prevent accidents and conserve efforts,

the hose may be anchored to the ladder with either a hose rope, a hose strap, or a hose chain (fig. 4-29).

a. As previously stated, it is difficult for one man to hold a nozzle of normal size which is discharging water from a  $2\frac{1}{2}$ -inch (6.35-centimeters) line. This feat becomes even more difficult on a ladder. Therefore, when water is being discharged from a nozzle while the nozzleman is standing on a ladder, the hose should be secured to the ladder a few feet behind the nozzle, or within the small-

est distance necessary to permit proper movement of the **stream**. Securing the hose in this way stops the nozzle reaction or kickback.

b. Frequently, when a nozzle is operated from ground level, not enough manpower is available, or too much nozzle pressure causes the nozzle to set up too much reaction to allow its safe holding. This situation may be remedied to a reasonable extent by shutting off the nozzle, looping the hose, and tying it to the forward end of the loop just far enough behind the nozzle to allow **maneuvera-**

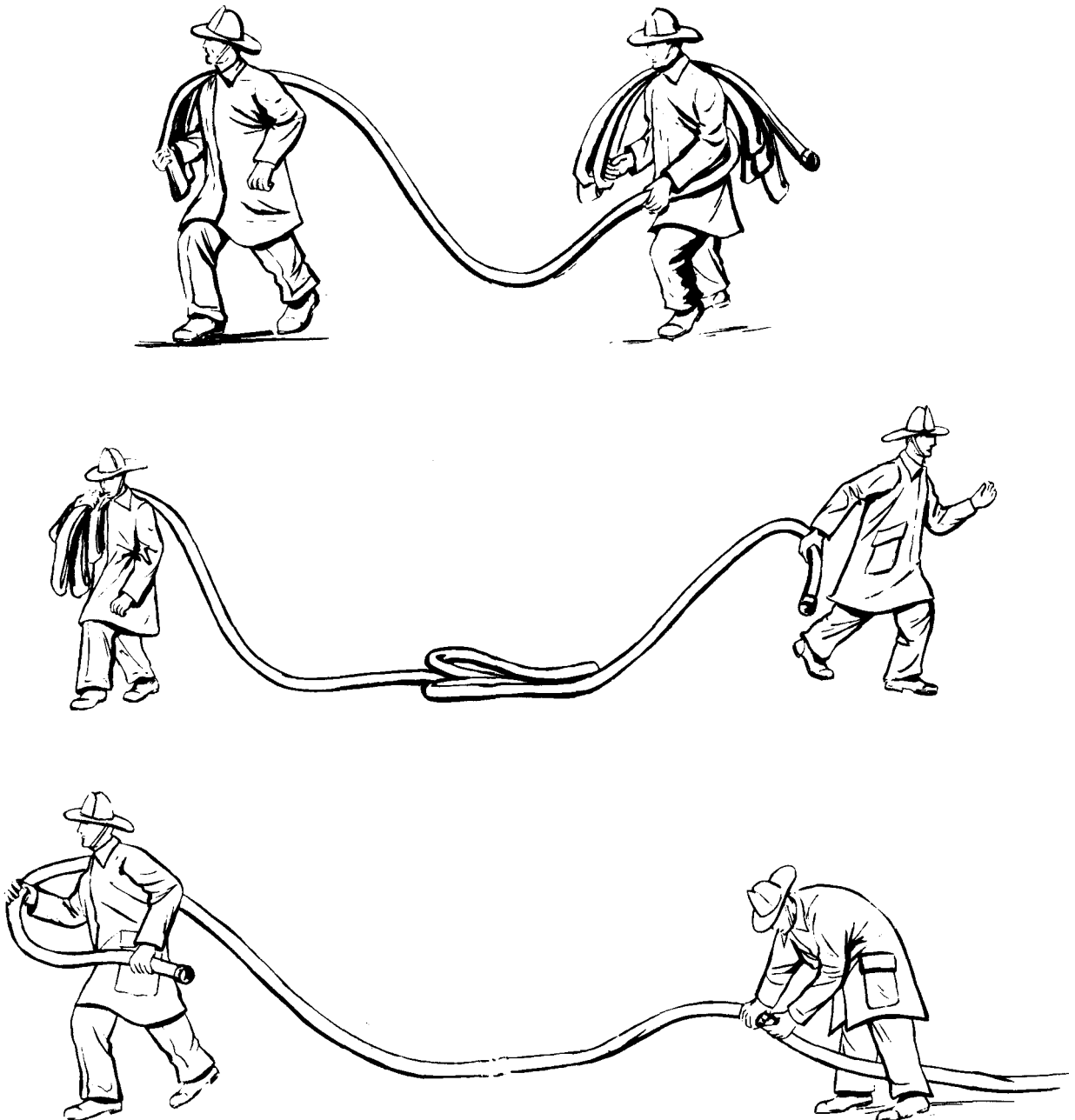


Figure 4-28. Lengthening a hose.

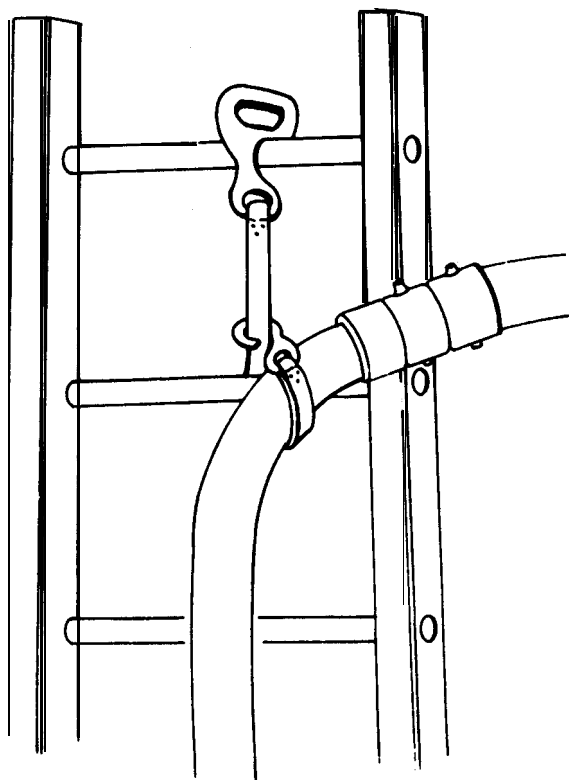


Figure 4-29. Securing hose to ladder with hose strap.

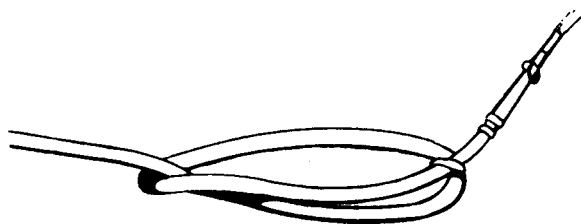


Figure 4-30. Securing hose against back pressure.

bility of the nozzle (fig. 4-30). Tying the hose in this manner increases friction loss somewhat and gives the hose a greater tendency to straighten itself. After securing it, however, one man should be capable of directing the stream. When movement of the hose is necessary, tying the hose in this manner is not recommended.

#### 4-30. Moving Hose lines

Hose lines when dry or uncharged must frequently be moved from one location to another.

a. When any great quantity of hose, such as several lengths, must be carried from one location to another, it normally requires the coordinated effort of several men to move the hose with any degree of speed and order.

b. Shoulder loads are formed by the first man, who starts with the nozzle or free end of the hose and places several layers or loops of hose over his shoulder in front and back ; but they must not extend so far as to interfere with his mobility. The next man will leave about 10 feet (3 meters) between the man in front of him and the point where he starts forming shoulder loads. This operation continues until all available manpower is utilized (fig. 4-31).

c. When a single **50-foot (15-meter)** section of hose is to be carried, a man places the main body of the hose on his shoulder and holds it with one hand (fig. 4-32). He uses his other to hold both couplings to prevent them from being dragged on the ground or damaged in some other way.

d. If a small **additional** length of hose is needed to reach the fire or to allow the hose to move to another area, a loop may be formed in the line and rolled toward the nozzle. This operation removes much of the zigzag slack from the line and lengthens it somewhat, thus increasing nozzle **mobility** and stream range efficiency-both from the standpoint of decreasing friction loss and increasing the range.

#### 4-31. ladders

A ladder is made of wood, rope, or metal, and is as definitely a part of fire service equipment as the hose, nozzles, or tools.

a. A firefighter must know how to carry, raise, and **climb** the different types of ladders issued by the Army. He should practice these procedures until the operations become as nearly automatic as is humanly possible.

b. The principal parts of a ladder are the sides, called **beams**, and the crossbars, called **rungs**. Ladder rungs are of the same design, regardless of the type of ladder. They consist of a round bar of **specified** size and strength.

c. Trussed ladders are designed as they are to make them stronger and lighter (fig. 4-33). A solid-beam ladder made of good material may meet the strength specifications, but it is much heavier than an equally strong trussed ladder, so the truss type is preferable. Trussed ladders are constructed with two beams on each side of the ladder. Some are made with one of the beams larger than the other **beam** on the same side of the ladder; others are made with all beams of equal size. With the former, the rungs are set in the



Figure 4-31. Hoving a hose line using shoulder loads.



Figure 4-32. Carrying a single folded section of hose.

larger beam, which is called the rung beam; the other beam is called the truss beam. Where the beams are of equal size, the rungs are set into blocks which are, in turn, set between the two beams.

d. The beams of wooden ladders are made of either Douglas fir or airplane spruce. The rungs of a wooden ladder are made of second growth hickory or ash. Many ladders are now being made of aluminum and are much lighter in weight.

#### 4-32. Kinds of ladders

Ladders currently being used by the Army are straight ladders, extension ladders, folding ladders, roof ladders, and Bangor ladders.

a. *Straight Ladder.* Straight ladders are sometimes called wall ladders and range in length from 10 to 40 feet (3 to 12 meters). In the Army these ladders are constructed on the exterior walls of buildings. They are used as auxiliary ladders only.

b. *Extension Ladder.* As the name implies, these ladders consist of two or more sections. The base section is called the bed ladder, and the other sections are the fly ladders. The fly ladder slides through guides on the upper end of the bed ladder and is equipped on the lower end with pawls, or dogs, that hook over the rungs of the bed ladder when extended to the desired height. The fly ladders are raised by a halyard that is fastened to the lower rung and operates through a pulley on the upper end of the bed ladder. Extension ladders are made in lengths from 14 feet (4 meters),

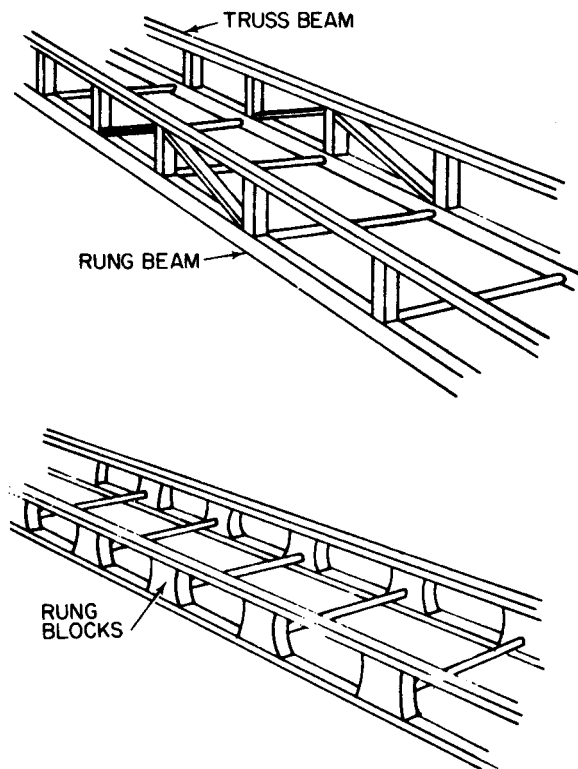


Figure 4-33. Trussed ladders.

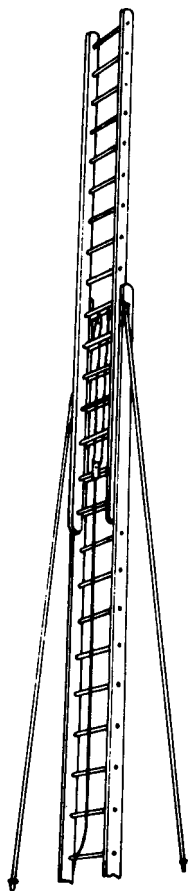


Figure 4-34. Bangor h&r.

called the “baby” extension, to aerial ladders of 160 feet (48 meters). However, extension ladders used most commonly by the Army are the 20, 24, and **36-foot** (6, ‘7, and U-meter) extensions, and the 40 and **50-foot** (12 and **15-meter**) **Ban-**gors.

c. **Roof Ladders.** Roof ladders issued by the Army have hooks mounted on a movable socket, which permits them to fold inward when not in use. Roof ladders range in length from 10 to 20 feet (3 to 6 meters). They may be of either the solid-beam or truss type. By placing the hooks of the ladders over roof peaks, sills, walls, or the coping of any opening, a fireman can climb the ladder with safety even though its butt may not rest on a foundation.

d. **Bangor Ladders.** A Bangor ladder is an extension ladder 40 feet (12 meters) tall or taller (fig. 4-34). Each side has a pole attached to it with a swivel. These poles are called tormentors. They have a spike in each free end, and aid in lifting and steadying the ladder while it is being raised.

e. **Folding Ladders.** A folding ladder is made up of two or more sections which are hinged for folding. A mechanism locks the hinges when the ladder is extended for use.

#### 4-33. ladder Carrying

a. **One-Man Carry.** Often a shortage of man-power makes it necessary for one man to carry and operate ladders. One well-trained man can do this, leaving the other men to perform the many other tasks necessary during an emergency. The roof ladder can be carried by removing it from the apparatus and passing either arm through the ladder at the middle of its length. The hooks should be carried forward and lowered (fig. 4-36). Extension ladders under 25 feet (7.6 meters) in length can be carried by positioning the shoulder at the center of the ladder with the heel forward, as shown in figure 4-36. This method allows the ladder to be set and raised in one continuous operation.

to 36 feet long (8 to 11 meters) require a minimum of two men, one near each end. After they have removed the ladder from the apparatus, each man passes one arm through the ladder and grasps the second rung forward (fi. 4-37). Both men must be on the same side of the ladder. The heel should be carried forward. When carrying a ladder in a crowded area, the lead man will use

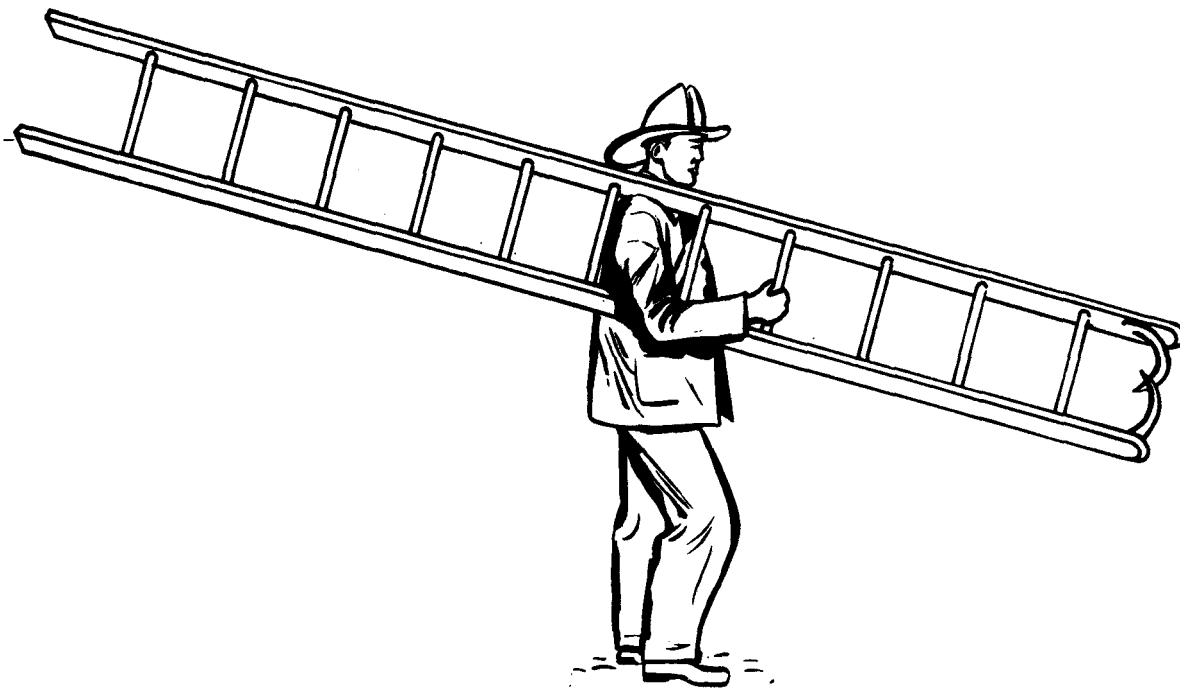


Figure 4-86. *One-man carry.*

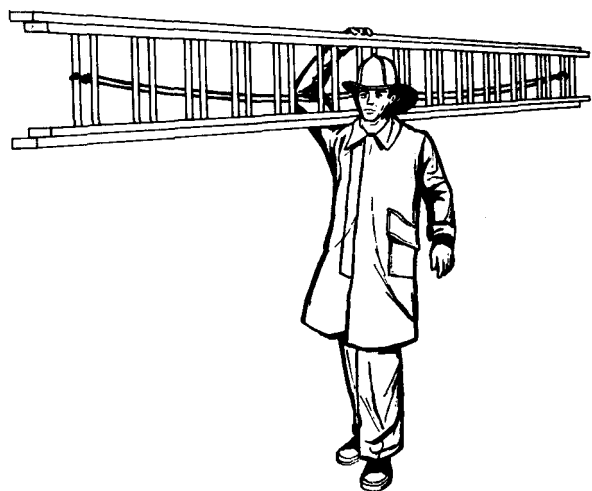


Figure 4-86. *One-man extension ladder carry.*

his outside hand to prevent injury to persons in the line of travel.

c. **Four-Man Carry.** Four men remove the ladder from the apparatus and place it on the ground with the fly of the ladder **up**. The men take positions, two near each end on opposite sides of the ladder. They face the top of the ladder, reach down, and grasp a rung with the hand nearer to it. They raise the ladder on their shoulders and carry it, as shown in figure 4-38.

d. **Six-man Carry.** This carry is used for the Bangor ladders and is the same as the four-man

carry, except that two additional men are placed in the middle on opposite sides of the ladder (fig. 4-38).

NOTE

Ladder drills tie in very closely with hose operations, because ladders are frequently needed for maneuvering the hose to an effective fire-extinguishment position. In addition, ladders are needed for rescue, ventilation, and salvage work, and for other fire fighting duties.

4-34. Ladder Raising

As in ladder carrying, ladder raising is an operation requiring practice and cooperation. Before a ladder can be raised, it must be determined how far the heel of the ladder should be placed from the building. There are two methods to determine this. One is to divide the length of the ladder by 5 and add 2. For example, if a **35-foot** (U-meter) ladder, fully extended, is to be used, the distance would be  $(35 \div 5) + 2 = 9$  feet (2.7 meters). The other method is simpler and more commonly used. The distance is determined by dividing the length of the ladder by 4. Thus, if a **35-foot** (11-meter) ladder is to be used, divide 36 (11) by 4 and the result is approximately 9 feet (2.7 meters) (fig. 4-39).

a. **One-Man Raise.** There are two methods by

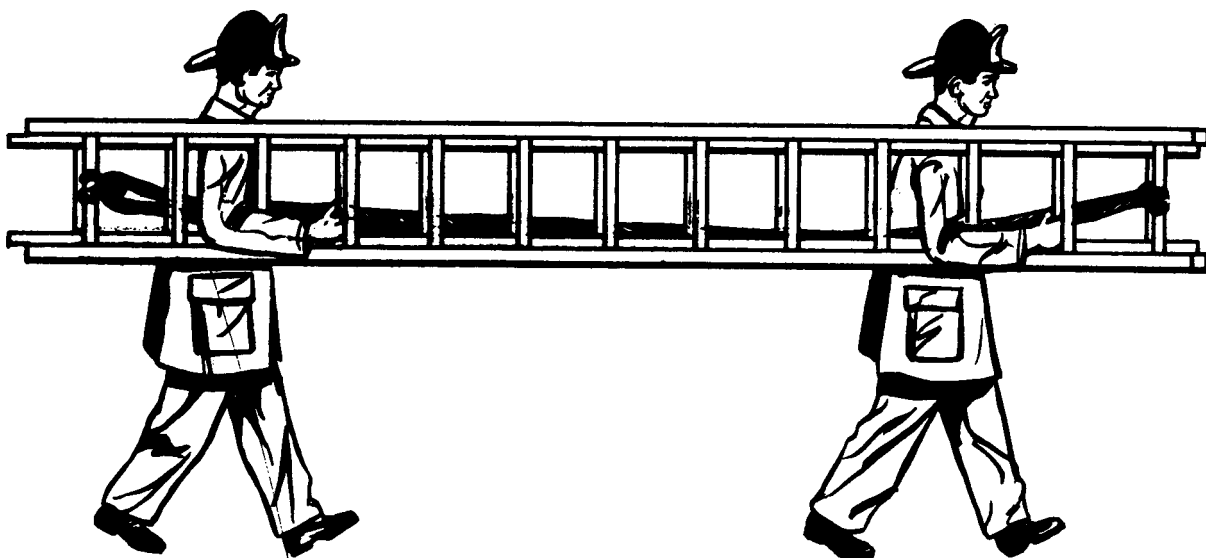


Figure 4-37. Two-man ladder carry.

which one man can raise a ladder. The first method, while slower, is easier for the beginner.

(1) Carry the ladder as described in paragraph 4-33 to the desired location.

(2) Place the heel of the ladder against the building.

(3) Grasp the top rung and raise the ladder to a vertical position while walking toward the heel, using every other rung (fig. 4-40).

(4) Grasp the ladder by the rungs with both hands, about three rungs apart. Lift the ladder off the ground and carry it back to the desired distance from the building.

(5) If the ladder is the extension type, step around in front of the ladder, grasp a rung at head height with both hands, and pull away from the building until the ladder is again vertical.

(6) Still facing the ladder, place one foot against the side of the beam, the knee against the front of the beam, thereby steadying the ladder. Allow the top of the ladder to lean slightly toward the building to counteract the pull of the halyard.

(7) Raise the extension to the desired height and lock the *pawls*. Lower the top so that it rests firmly against the building (fig. 4-41).

#### NOTE

The other method of the one-man raise is faster but requires more skill. Carry the ladder as shown in figure 4-35. When the heel of the ladder is at the desired position, start pressing down on the heel, with the hand holding the ladder; when

the heels are nearly parallel with the ground, lean forward and give a sharp push with the shoulder. This will set the ladder in the vertical position. Raise the extension as described in (5) through (7) above.

*b. Two-Man Raise.* When enough manpower is available, two men should be used for raising 24 and 26-foot (7 and 8-meter) ladders. The following method should be used:

(1) The ladder is removed from the apparatus and carried to the desired position.

(2) The heel should be spotted at a point directly below where the top is to rest.

(3) Where there is enough distance between buildings, the ladder is positioned at right angles to the target building; otherwise the ladder must be positioned parallel to the target building. The ladder is laid flat with fly ladder up.

(4) The man designated to heel the ladder stands on both heel plates, reaches forward and grasps a rung with both hands, and then leans back to assist in the raising.

(5) The other man stands at one side of the ladder, facing the top. He reaches down and grasps a rung near the top, raises the ladder over his head, swings in under the ladder facing the foot, and walks toward the foot using every other rung. If the ladder is positioned parallel to the building, both men grasp the beams and swing the ladder around with the fly inside.

(6) The two men are now facing each other through the ladder. The man on the inside stead-



Figure 4-38. Four and six-man ladder carries.